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Arc-Welding Progress that Tends to Eliminate the Human Factor

The advent of the shielded-arc process and the development of improved equipment and of improved technique are gradually removing stultifying restrictions and promoting the advancement of the art.

THE dependence of welding on the human factor, or, in other words, on the manipulative skill, judgment, and conscientiousness of the welding operator, has undoubtedly much retarded the use of the process in the past, even although its considerable economical advantage has been generally recognised. It is, therefore, natural that much recent research and resulting improvements have been directed to eliminate this doubtful element. By the recent introduction of what is now commonly termed the "shielded arc," a very considerable forward step has been made in this direction.

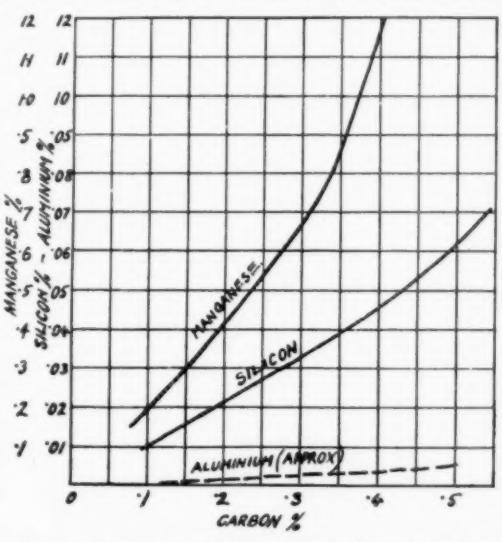
The extent of the operator's skill and care has, in the past, been chiefly directed to prevent slag and gas inclusions, to ensure complete fusion and penetration, and the maintenance of a short uniform arc in order to prevent burning and oxidation of the weld metal and the formation of nitrides.

A brief description of the shielded arc process will sufficiently indicate how these operations are independently accomplished by its use.

As its name implies, the arc is shrouded or enveloped. This is effected by sheltering the arc and fusion area in an envelope of inert gases from which the air is entirely excluded. The high temperature of the electric arc evolves these gases from suitable material in considerable quantity. They consist chiefly of carbon dioxide as the inert shield, and a small amount of carbon monoxide which acts as a deoxidiser, uniting with the active elements of the air seeking their way within the outer envelope.

Thus, within this inert protection there is not the same necessity on the operator's part to maintain despite unevenness of working surface and fatigue, the rigidly close and uniform arc formerly necessary. The process, in fact, employs quite a long arc, which, together with increased welding currents and other factors beyond the scope of this article, result in considerably greater welding speeds and reduced costs.

It is this increase of welding current, together with the longer arc, which to a great extent eliminates the possibility of slag inclusions. These are caused commonly by an excess of slag being entrapped in the metal when it solidifies, and it has been the operator's duty as best he could to keep this slag material pushed up on top of the weld. However, the shield-arch method practically frees him from this task, first by requiring a minimum of slag, and secondly, by producing and maintaining a large volume of molten weld, which affords an opportunity for all slag and impurities to float on top of the liquid as in a steel furnace. This is further aided by the natural agitation of the stronger and more pronounced arc blow, which is itself more inherently concentrated and directed by the process.



The Lincoln-Stine equilibrium curve for determining the analysis of steels best adapted for arc-welding. Steel for arc-welding selected in accordance with these curves should produce welds free from slag holes or porosity of weld metal. Aluminium additions to welding steel, however, should be avoided or kept to a very low amount because aluminium content is difficult to determine by analysis, and the presence of aluminium oxide is objectionable because of its high melting temperature which lies between the maximum steelmaking temperature and maximum arc-welding temperature.

In the same way, gas inclusions are prevented, due chiefly to the puddling nature of the process as distinct from the practice of depositing, with minimum current and voltage values, increment upon increment of weld metal, each freezing on the one previous, before slag or gases have time to escape. As is obvious for the same reasons, complete fusion and penetration are more adequately ensured.

It probably should be pointed out that such high currents as are used by the process are quite permissible, since the arc and fusion area are adequately protected. In the past it has been the inadequacy of such protection which has chiefly restricted current values and sponsored the advocacy of small-diameter electrodes, with resulting low welding speeds and higher welding costs.

Adequate fusion and uniform penetration are, however, together with other variable factors, more definitely assured by the use of the modern automatic welding processes employing, with other ingenious features, the same use of the shielded arc. With this type of equipment it may be safely said that the human factor, once the machine is properly adjusted, is entirely eliminated. It is this vital factor which, in conjunction with greatly reduced welding costs, has advanced this process so very rapidly.

Here no factor is left to chance or the operator. The shielded arc prevents the formation of oxide and nitride in the weld metal, heavy welding currents produce a volume of molten metal automatically controlled, puddled, and clarified by means of a revolving magnetically controlled arc. A precisely uniform arc length under all conditions is automatically maintained, as well as predetermined

current values and speeds. Thus it is that the human factor has been practically eliminated from welding, and the idiosyncrasies of the operator replaced by the unemotional skill of processes and machines.

The advent of the shielded arc has, of course, not alone been responsible for all recent progress of this nature. The recently published Lincoln-Stine equilibrium curve for the selection of welding steel, which is reproduced in the accompanying graph, has proved and will prove a very vital help. In general, these curves record for a given carbon content the desirable amounts of other important elements necessary to obtain chemical equilibrium of reaction within the steel when subject to arc-welding temperatures. To illustrate the use of this equilibrium curve it is convenient to give an example. To ascertain the proper analysis for a 0.18 per cent. carbon steel find 0.18 per cent. on the lower line and follow up vertical line to silicon curve, follow horizontal line to left which indicates 0.19 per cent. silicon, then follow up vertical line from 0.18 per cent. carbon to manganese curve, then along horizontal line to left which indicates 0.37 per cent. manganese. Thus, the evolution and absorption of gases and other impurities is prevented or obtained in a non-detrimental form. As is obvious, this established a definite point from which to evolve suitable fluxes to counteract such deficiencies in commercial steel, and has already been used as the basis of such.

It should be mentioned also that continued improvements in welding machines, due principally to their inherent stable arc characteristics, compensate for much lack of skill and care on the part of the operator. Manufactures of such welding equipment have indeed done much to promote the advancement of the art in this respect.

Reviewing the situation in the light of recent progress, it seems quite probable that electric welding employing the shielded arc will shortly be accepted under most codes for high-pressure vessels and boilers without the stultifying restrictions to which they have in the past been subjected. In fact, the process has found its greatest application and received its initial development in this exacting sphere. Manufacturers of heavy pressure vessels and boilers who, with the advent of heavy plate thicknesses, increased internal pressure, temperatures and corrosion problems found other methods of fabrication inadequate, and were driven to find some more improved method of fusion welding.

The shielded arc produced the necessary results, and is now the accepted method in this most difficult field amongst the leading firms of the industry, especially in the United States, and to an increasing extent in this country. In the former, however, the process has had more time and opportunity to prove its adequacy, with the result that it is now generally accepted by insurance companies for work of this nature, and has been mainly responsible for the recent revision by the American Society of Mechanical Engineers of those codes regulating such fabrication, to permit the use of electric welding.

In establishing the proper procedure for this type of welding, and confidence in its use, the X-ray and Gamma ray have proved helpful factors, and are at present used as a method of checking results, and where regulations require, of inspecting all welded seams. However, it is being found less and less necessary to resort to the latter procedure, and with continued familiarity with the process it will likely be considered inexpedient to subject all seams to such a cost-prohibitive procedure. The shielded-arc method has proved its sufficiency, and it is to be hoped that those in the future framing codes and regulations governing vessels and structures so fabricated will not unduly increase the cost of manufacture by demanding such costly tests when present results are already proving these generally unnecessary.

It is an interesting thought that after years of search on one hand for a welding process which required no elaborate test, and on the other for some such actual means of testing that both should seem to arrive to the aid of industry almost simultaneously.

STEEL STRUCTURES.

THE Steel Structures Research Committee, of which Sir Clement Hindley is chairman, has published its first report. The Committee was appointed in August, 1929, and it had for its object a review of present methods and regulations for the design of steel structures, including bridges, and a consideration of the application of modern theory to the design of steel structures, including bridges, so that recommendations could be made for the translation into practice of such of the results as would appear to lead to more efficient and more economical design.

The remarkable change that has taken place in the building industry during comparatively recent years is due to the increasing use of steel. Indeed, modern types of architecture have only been possible as a result of the scientific use of steel. Yet it is only thirty-five years since the first steel-frame building was erected in this country. Steel undoubtedly provides the most economical as well as the safest means of support for the heavy loads now carried, and makes possible the wide spans employed in many modern buildings. At the same time, its use facilitates speed of erection, and enables the height of buildings to be increased with complete safety: the advantage of which is of considerable value in these days of high site values. The natural desire of the steel industry is to extend the use of steel, and in their efforts to promote its increasing usefulness they adopt the very thoughtful and far-seeing view that systematic progress is only possible with improved technique and practice. It was with the object of applying the fundamental scientific principles that the steel industry asked the assistance of the Department of Scientific and Industrial Research, which resulted in the appointment of this Steel Structures Research Committee.

The report is divided into six sections, which includes: (1) Special investigations in relation to practice which includes a comparison of existing regulations governing the design of steel-frame buildings in Great Britain and the Dominions, as well as other countries. (2) Investigations concerning strains in buildings. (3) Stresses in building frames. (4) Materials. (5) Struts. (6) Welding of steel structures. Each of these sections has been considered by a sub-committee.

Results of considerable importance have already been obtained for the conclusions reached in one section have been embodied in a suggested new code suitable for adoption. While this code is presented in a form in which its findings may be readily used in drafting a building specification, the Committee emphasises the fact that it is a research body, and not, therefore, directly concerned with administrative action. Consequently its rules of practice must be distinguished from the final framing of any legal regulation embodying them. The code is conceived on lines which allow for elasticity and modifications as scientific knowledge advances.

In regard to strength of welded joints, the Committee state that structural welding codes and regulations have been based on data obtained mainly from tests on small specimens, and on such practical experience as was available; but the need for further research is apparent. A table is included in the report which shows the permissible stress in welded joints under various regulations in America and Germany, and further information is given about tests carried out on full-sized welded joints. The Committee states that perhaps the greatest obstacle to the general application of welding to building construction is the impossibility at the present stage of development to guarantee the soundness of all the welds in a large structure. The report is a lengthy one, and full of valuable technical information on steel structures.

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Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part X.— Hot Mills.*

The several types of mills used for the hot break-down operation on aluminium and aluminium-alloy sheet ingots are discussed in this article.

THREE-HIGH mills have been favoured by some operators, particularly in Continental Europe, for aluminium hot rolling, but so far have found little application in American practice.

The three-high mill consists essentially of three superimposed rolls, suitably mounted in a housing. Ordinarily, the top and bottom rolls are of the same diameter and the middle roll is of smaller diameter. Constructional details vwry more or less with different builders. In the rolling, the ingot or partly broken slab is sent between the bottom and middle roll in one direction, and on the return pass is sent between the top and middle roll. The work is handled on lifting or tilting tables placed on either side of the mill, these tables being positioned to receive or feed the slab according to the direction of passing. Tables may be equipped with loose or power-driven rollers, and are mechanically actuated. Fig. 5 shows a sketch which illustrates the principle of operation of the three-high mill. At one plant in Germany, aluminium-alloy ingots are broken down on a 55-in. three-high mill. Fig. 6 shows a view of a three-high hot mill in shop erection: the rolls are about 53 in. face length.

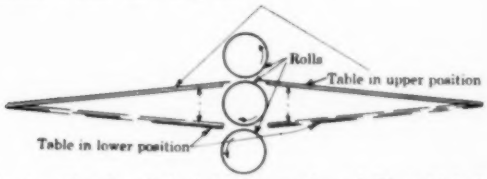

Fig. 5.—Showing Principle of operation of Three-high Mill.

Three-high mills for aluminium hot rolling are built by various firms: certain German houses have been foremost in promoting this type of equipment. Thus, such mills are built by the following companies: Engelhardt Achenbach Sel. Söhne, G.m.b. H., Buschhütten, kr. Singen: Sundwiger Eisenhutten Maschinenbau-Aktiengesellschaft, Sundwig, Kr. Iserlohn: and Schloemann Aktiengesellschaft, Düsseldorf. The largest three-high aluminium hot mill so far employed has recently been built by the latter concern for use in the United States. This mill has rolls measuring 44 in. (top and bottom), and 28 in. (middle) in diameter by 144 in. body length. Drive is by two 3,000-h.p. D.C. motors, through reduction units. This mill has been described by Pfann.[3]

Hot-mill Rolls.

Rolls for aluminium hot mills are usually made of chilled cast iron, but forged steel rolls have also been used. The plain chilled cast-iron roll costs about one-fourth as much as the forged and heat-treated steel roll, but the former has a much greater tendency to fire-crack, and consequently has shorter life than the latter. Chilled alloy cast-iron rolls are favoured by some operators in preference to the plain chilled rolls. Alloy cast-iron rolls cost 60 to 100% more than plain cast-iron rolls. Unfortunately, insufficient data are available regarding the effect of composition and hardness of hot-mill rolls on the performance and life to settle definitely the question as to what is the most economical roll. Hence, an operator may well hesitate to pay 10 or 20 cents per lb. for a special roll unless he

(*Continued from November issue, page 22.)

[3] E. Pfann, "Modern High-Efficiency Machinery for the Manufacture of Non-ferrous Metal Products," *The Metal Ind.* (London), vol. 38, 1931, pp. 83–86.

knows that the probable life will be almost twice or four times as long as that of the plain chilled roll at 5 cents per lb. Of course, the questions of roll changes and number of dressings are necessarily to be borne in mind.

The ordinary plain chilled cast-iron roll as made for aluminium hot mills has scleroscope hardness of about 55 to 60, and a typical analysis of the iron is as follows: Total carbon, 3·15%; silicon, 0·76%; manganese, 0·35%; sulphur, 0·14%; and phosphorus, 0·31%. Allison[4] gives the following range of composition for some chilled-iron rolls: Total carbon, 3·09 to 3·68%; silicon, 0·65 to 0·85%; manganese, 0·27 to 0·37%; sulphur, 0·13 to 0·22%; and phosphorus, 0·23 to 0·33%. The scleroscope hardness range was 55 to 71. Alloy cast-iron

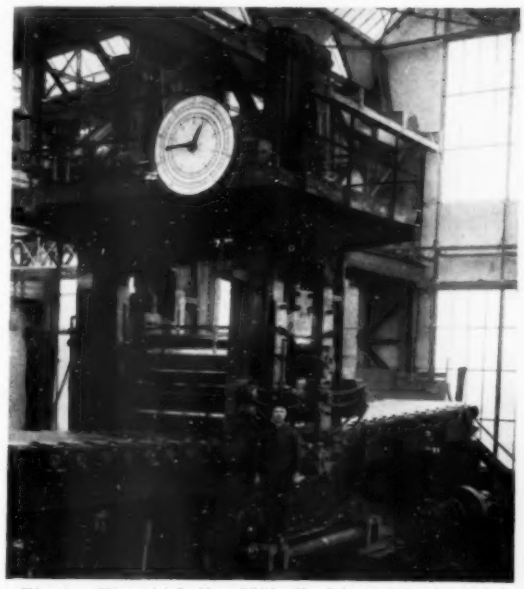

Fig. 6.—Three-high Hot Mill (Englebert Achenbach Sel Söhne, G.m.b.H.)

rolls are made by additions of molybdenum, chromium, or nickel (or chromium and nickel) to cast iron of suitable composition. Roughly, the addition of alloying metals increases the hardness of the chill face, produces a chill of more uniform depth, makes the grain finer, and toughens the core. The average hardness of alloy cast-iron rolls is about 70 to 75. The Achenbach firm, above mentioned, produces chilled rolls with a scleroscope hardness of 85. Chromium-alloy steel rolls are made with scleroscope hardness of about 100. In the case of chilled cast-iron rolls, it is usually specified in American practice that the depth of clear chill shall be $\frac{7}{8}$ in., allowance of $\frac{1}{8}$ in. either way being made—that is, the chill depth varies from $\frac{3}{4}$ in. to 1 in.

The scleroscope hardness of a chilled roll is not a reliable guide as to probable performance in service and may be very misleading. More important factors are apparently the physical structure of the core, and certainly the depth

[4] A. Allison, "Chilled Iron Rolls," *Foundry Trade Jour.*, vol. 38, 1928, pp. 259–261; 277–278; and "The Manufacture of Chilled Iron Rolls," Sir Isaac Pitman and Sons, Ltd., London, 1929, 120 pp.

of chill, condition of the body face after grinding, and the accuracy of grinding of the body with respect to the necks. As pointed out by Allison,[5] in discussing chilled rolls in general, the chill should be sufficiently deep to provide reasonable life with repeated grindings, but not so deep as to make the roll mechanically brittle. Broadly speaking, the harder the chill and the greater its depth the shorter will be the life of rolls in aluminium hot-mill practice. This follows because the expansion on heating will be greater, and therefore the onset of fire-cracking will be earlier. The cause of fire-cracking has been discussed by the writer[6] in the previous article of this series.

On finishing, the chilled roll should grind out free of pinholes, checks, hard spots, and other imperfections, and have a bright mirror-like finish. The necks and the body must be "true round," and true to each other. Necks should be ground to ± 0·001 in., and this tolerance may be specified on bodies ground flat. Hot-mill rolls should preferably be ground with a slight concavity in the body to counteract expansion, the amount of concavity necessarily varying with the diameter and length of the roll and the normal temperature of operation. Lesser, or no, concavity may be provided when the rolls are flushed with a lubricating coolant, as contrasted with lubricating with oil and periodic water cooling.

The life of hot-mill rolls may be measurably prolonged by operating at as low a temperature as possible (*i.e.*, by the use of a lubricating coolant in rolling), preventing sudden or wide changes in temperature, by prompt dressing when small cracks develop, good lubrication of the necks, and avoidance of stickers. The general practice of allowing hot-mill rolls to cool to room temperature when the mill is shut down is not good. An electric roll heater might be used to advantage to maintain the temperature at about 150° C. or so. Fire-cracked rolls may be reconditioned by grinding off the cracked surface to sufficient depth, and rolls may be used until the chilled surface has been ground down to about three-fourths of its clear depth.

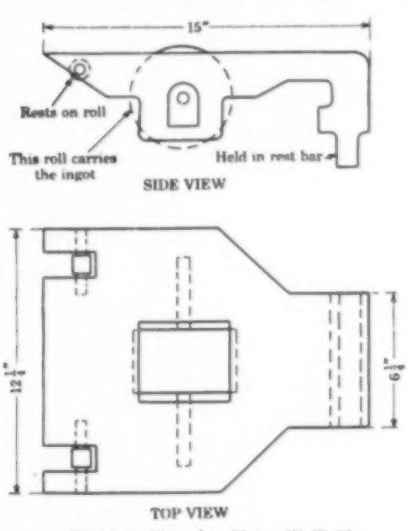

Fig. 7.—Shoe for Hot-mill Table.

Some Accessories and Fittings.

In the choice and purchase of hot mills, operators are necessarily limited to the equipment available and standard with builders unless considerable extra expense is incurred in the design and production of special equipment. Practical experience has shown that some types of mills as supplied are faulty, defective, or at any rate do not operate as satisfactorily as is desired in certain particulars. Hence, parts of the mills have to be rebuilt, certain changes made, or special fittings attached in the plants where used. True enough, such changes may sometimes do more harm than good, but they are continually being made by mill superintendents and master mechanics. Assumably, the engineers of a machinery builder should know more about the proper design and construction of mills than the practical aluminium sheet-mill man. On the other hand, the mill operator is in a better position to observe the performance of the equipment, and the mill mechanic, who takes care of the maintenance, is in a better position to discover weaknesses than the builder. Naturally, close co-operation of builders and users is the solution to the problem of satisfactory performance. This applies, of course, to cold mills and other machinery in the plant.

An example of a hot-mill fitting that has given more or less trouble in practice is found in the case of table shoes or plates. On two-high non-reversing mills the feed table on the roller's side may consist of a series of loose rollers, the one nearest to the rolls being set about 2 in. to 3 in. from the lower roll. The receiving table may consist of a similar series of rollers, but special plates or shoes are placed between the lower roll and the roller nearest to the rolls. These shoes are used for the purpose of guiding the slab on to the table and preventing it from riding down into the pit or causing damage to the table in case it tends to stick to the lower roll. On two-high reversible mills, both the feed and receiving tables may be of the same design as the receiving table on two-high, non-reversing mills—*i.e.*, special shoes are positioned close to the lower roll.

In one design, applied to a two-high, irreversible mill, a series of cast-iron fingers, having small rollers on the ends, is mounted on a heavy rod set between the housings. This rod is positioned immediately ahead of the roller of the table nearest the rolls, and the fingers are rotatable on the rod. With this fitting, if a slab pushes on the ends of the fingers, they fly back, thereby removing the strain and allowing the slab to move. If the fingers are rigid, the drive of the slab may break the plate.

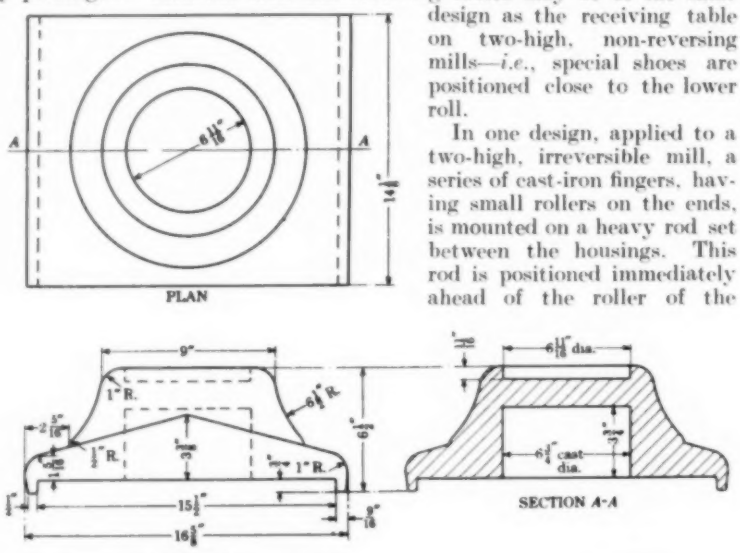

Fig. 8.—Design of Breaker Block for Aluminium Hot Mill.

Another design of table shoe, applied to a two-high reversing mill, is shown in Fig. 6. A series of such shoes is mounted in rods, extending from housing to housing, on either side of the mill. In some similar designs the tapered end of the shoe rests on the lower roll. Such design is not satisfactory, since the shoe tends to scrape the lubricating coolant off the roll and cause splashing. In the design shown, two small case-hardened rollers are inserted in the tapered end, these rollers bearing on the lower roll of the mill. The large roller of the shoe carries the ingot (or slab), from which the latter rolls back to the main table. More satisfactory performance has been had with the design of shoe shown than with similar shoes which ride on the roll.

Any hot mill should have a known and specific point of weakness where failure may occur, due to overloading, strain, or stickers, without damage to other more expensive parts. Such point of weakness is provided by the use of

(*Continued on page* 40.)

[5] A. Allison, *loc. cit.*
[6] R. J. Anderson, *op. cit.*

Correspondence.

The Editor, METALLURGIA.

The Polarising Metallurgical Microscope.

Dear Sir,—I have read with pleasure the report on "The Micro-optical Investigation of Non-ferrous Alloys by Polarised Light," by Dr. Schwarz, in your October issue, and it occurred to me that further detailed information would be helpful to your readers. In the examination of metal specimens with the ordinary metallurgical microscope, the surface of the metal to be examined is etched with acids or alkaline salts after being carefully polished. This makes the crystalline microstructure appear distinctly. There are many different methods of etching, and careful choice is necessary, according to the qualities and chemical composition of the metal, in order to obtain the desired results. Even with every care, a perfect and faultless development of all structural details will not be obtained in every case.

A new method by which distinctions are made possible, frequently when other methods have failed, is by examination in incident polarised light, with the aid of a special instrument known as the polarising metallurgical microscope. In this method of investigation no etching of the specimen is necessary, the surface being merely polished and not treated chemically. The crystals, particularly of light alloys and of many ores, frequently show anisotropies, which appear in the double reflection, and may therefore easily be observed in polarised light.

The polarising metallurgical microscope shown in Fig. 1 is an illustration of the instrument constructed at the instigation of Prof. von Schwarz, with which he made a series of examinations and produced coloured micro-photographs from metal and ore specimens, many of which were reproduced in colours in your journal.

This microscope is of the vertical type, which for examinations in polarised light, is preferable to the reversed type generally used, because every reflecting surface brought into the path of the light rays would emit elliptic polarised light, which would greatly interfere with the observation. A component of the Reichert polarising metallurgical microscope—the polarising opaque illuminator—is illustrated in Fig. 2. The source of light, a low-voltage lamp of 0·6 amp., is incorporated in the illuminator, thus ensuring a constantly centered illumination, even if the microscope tube is repeatedly adjusted. The light supplied by the low-voltage lamp 9, collected by a system of lenses 7, 8, and passed through the polarising Nicol 6, rotating by means of the handle 15, is thus polarised linearly. A rectangular prism 5 deflects the pencil of light, directing it into the objective, which, in its turn, concentrates the light on the surface of the specimen. Only half of the objective is covered by the rectangular prism, leaving the other half free for the light rays forming the image. A second Nicol, the analyser 1, is incorporated in the tube of the microscope. By conveniently rotating the polariser, the undulating direction of the two Nicols is crossed, and observation is made on a dark field of view.

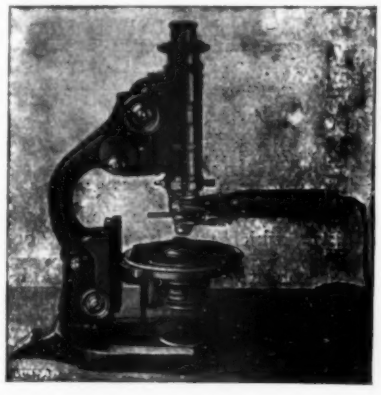

Fig. 1.
Polarising Metallurgical Microscope.

The object stage of the microscope rotates, and has a circular division with verniers. When rotating double-refracting crystals, between crossed Nicols, the colours of polarisation clear up and darken alternately, permitting the different components of an alloy in an unetched specimen to be identified. With the aid of the circular division on the object stage and the cross-line eye-piece, the cross lines of which indicate the undulating direction of the Nicols, the angles may be measured, which gives information about the nature of the crystals, and permits the identification of the structural components of the specimens.

In order to keep an object which is focused in the centre of the field of view constantly centered, the tube of the microscope is provided with a centring device for the objectives. The tube analyser can easily be swung out for investigations with ordinary non-polarised light.

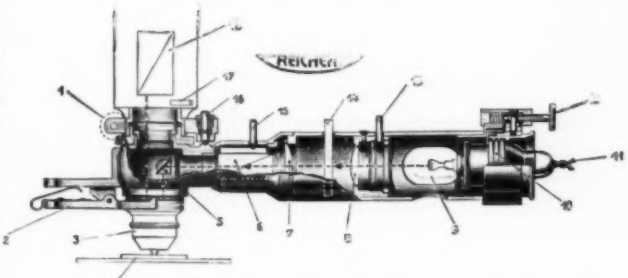

Fig. 2. The Reichert Polarising Opaque Illuminator.

A photo-micrographic apparatus for taking ordinary black-and-white or coloured photographs of the structural images in polarised light, can be readily fitted to the microscope. In this case, the low-voltage lamp of the opaque illuminator is replaced by a low-voltage lamp of greater specific luminous intensity, which is secured to the microscope tube by means of a holder.

Prof. Schwarz, in his article, gives an account of the adoption and the results of this method of investigation. There are still other important phenomena which may be observed with the polarising metallurgical microscope. The peculiar colours of inclusions are distinctly visible. Inclusions of cuprous oxide, which in incident non-polarised light are of grey colour, will appear deep crimson in polarised light with crossed Nicols. This not only facilitates the identification of inclusions of cuprous oxide in copper, but also permits a clear distinction between cuprous oxide and cuprous sulphide. In non-polarised light the latter also has a grey-blue colour, whilst it will appear black between crossed Nicols.—Yours etc.,

C. REICHERT.

Optical Works, Vienna,
November 20, 1931.

[The above letter was received too late for publication in the November issue, but it has lost nothing in interest as a result of delay.—EDITOR.]

TESTING OF ELECTRIC WELDING.

The Editor, METALLURGIA.

Dear Sir,—It is important to note that although the authors of the paper, "Welding in Boilerworks Practice," to which you referred in your November issue, expressed the opinion that no lasting progress with electric welding would be made without the aid of X-ray apparatus, they did not advance reasons, for this expression of opinion, other than to point out the advantages of being able to observe any defections in the weld. It is a pity that more discussions were not devoted to this point, in order to ascertain what reasons if any, were responsible for such an opinion. One might be led to conclude that the percentage of failures that follow in the wake of welded construction is such that its employment for pressure vessels is risky and even dangerous.

Given good plant, material, and, above all, good operators, it is difficult to adduce why electric-welded joints require more inspection than any other method of joining parts. It is taken for granted that the riveter closes down a rivet that fully fills the hole and is tight; if it does not shake under a tap from a toffee hammer, it is judged to be sound. Nobody questions a blacksmith's shut until it fails, and then the blame falls on the smith, not on the method. The same thing, of course, applies to brazing, soldering, plumbing, and even joining; if the job fails the operator is to blame. Yet in the case of electric welding the fallacious idea prevails with many people that unskilled and untrained labour is good enough. Nothing could be farther from the truth. Electric welding, to be sound and reliable, demands expert, conscientious, and intelligent handling, and the choice of suitable materials.

Manufacturers are now beginning to realise this, as evidenced by the fact that several large firms have set up their own welding schools in which to train operators to the necessary standard of proficiency. No one will disagree with the employment of X-ray or any other reliable method of examination. In fact, some means of testing in cases where doubt exists as to the skill of the welder or suitability of material used is highly desirable. But this is a far different thing from saying that the science cannot progress in important work without the aid of same. To our certain knowledge, electric welding is extensively and increasingly used in the construction of pressure vessels, and in the vast majority of cases that have come under our notice better service has been obtained and bigger economies effected both as regards initial cost and maintenance by this means than the older methods of construction.—Yours etc.,

For and on behalf of
MUREX WELDING PROCESSES, LTD.,
Ferry Lane Works, J. E. KENNARD,
Forest Road, Walthamstow, E. 17., *Research Eng.*
November 30, 1931.

One-ton High-frequency Induction Furnace.

THE advantages of the high-frequency coreless-type induction furnace for the production of high-grade steels and ferrous or non-ferrous alloys, are rapidly becoming appreciated in the British metallurgical industry. As a result of the successful operation of a Metrovick ¼-ton furnace of this type in the works of Messrs. Thos. Firth and John Brown, Ltd., of Sheffield, a further order for a 1-ton furnace installation has been placed by this firm with the Metropolitan-Vickers Co., of Manchester. This will be the largest high-frequency induction furnace installed in England.

Experience has shown that steel of a quality in every way equal to that of crucible steel can be produced by a ¼-ton high-frequency induction furnace at about half the cost of the older method, and it may be confidently anticipated that the use of larger furnaces of this type will lead to a further reduction in the cost of producing high-grade steels. It is estimated that the use of the larger unit will show a reduction in running costs, including depreciation, interest on capital, and overhead charges, of about 30% when compared with those of the present ¼-ton furnace. The Metrovick 1-ton furnace is generally similar to the ¼-ton furnace, of which there are a number in operation throughout the country, but a brief description of the larger unit may be of interest.

The complete installation includes the furnace, high-frequency motor generator, switchgear, and a bank of static condensers for power-factor correction. The furnace box, containing the water-cooled coil which surrounds the charge, is mounted in a framework of non-magnetic steel, in order to avoid any risk of over-heating due to stray magnetic field from the coil. The latter is of the patented construction developed by the Metropolitan-Vickers Co., being wound with ½ in. copper strap with a tube on the outer edge for the circulation of cooling water. This form of construction has great advantages in efficiency, mechanical strength, and safety.

The safety of this construction is a particularly valuable feature. During the early stages of development it was shown conclusively; even when some of the molten metal was allowed to break through the crucible and sand-filled space which normally separates the charge from the inside of the coil, no damage whatever was done.

The furnace-tilting mechanism is driven by a mechanism which can be finely controlled for both backward and forward tilting, thus facilitating the removal of slag and providing accurate control of pouring operations. The motor generator set consists of a single-phase 500-cycles, 2,000-volt alternator with overhung exciter, directly coupled to a 1,500 r.p.m. slip-ring induction motor, the rating of the latter being 1,100 b.h.p., and that of the generator 600 k.w., at unity power factor. The output is such that the full furnace charge of 1 ton can be melted in approximately one hour.

The switchgear, with the exception of the starting equipment for the motor generator, is of the electrically operated type, and includes a furnace switch cubicle fitted with an electrically operated circuit breaker, protective relays, instrument transformers, etc., a condenser panel, a remote-control board located on the furnace platform, and a small controller for the tilting mechanism. The remote-control panel is fitted with instruments for indicating voltage, current, and power factor, and with push buttons for operating the alternator circuit breaker.

The voltage and power factor are both automatically controlled, the former by a voltage-regulating relay, and the latter by a power factor regulating relay which, by means of contactors, switches in and out sections of a bank of static condensers. The furnace normally operates at unity power factor. The provision of these automatic features has the great advantage of leaving the furnace operator free to concentrate almost entirely on the metallurgical requirements of the melting process.

This installation is founded on the successful operation of smaller furnaces of the same type and is a recognition of the important economies and operating advantages gained by the use of the high-frequency induction furnace as compared with older and more expensive methods. Its installation is also a further step in the modernisation of the British steel industry.

Aluminium Sheet Production

(*Continued from page* 38.)

breaker blocks, these blocks being placed between the upper roll carriers and the lower ends of the screw-downs. A design of breaker block used on one mill is shown in Fig. 7. The breaker block is designed as to strength, section, and material to withstand a certain tonnage pressure, so that in event of overload it will crush in: thus, the breakage of pinions, roll carriers, roll necks, and possibly rolls, may be prevented. Grey cast iron is a suitable material for making breaker blocks.

Hot-mill screw-downs, particularly in the case of two-high reversing mills, are subjected to severe service. Bushings, which may be made of hard phosphor bronze, should be replaced whenever looseness results, due to spread or wear of the threads.

Leaded and phosphor bronzes are used for roll-neck bearings on hot mills. Ordinarily, new bearings are put in whenever a roll change is made, at which time the entire mill may be given a general overhauling. Bearings may, of course, require replacement whenever they show a tendency to pound out.

The lubrication of hot mills will be taken up in a later article of this series, when dealing with the question of maintenance.

In the next article the planning of aluminium sheet production is discussed.

METALLURGIA

The British Journal of Metals.

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METALLURGIA

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The Question of Tariffs.

IT was fully recognised that one of the first objects of Mr. MacDonald's Cabinet, on attaining office, would be to inquire into the trade balance, and explore every avenue for means of restoring it to a normal condition, before asking for powers to effect remedies. No information is available of the Cabinet's deliberations on trade balance, but they asked for and were given authority to impose emergency duties on articles which were proved to the satisfaction of the Board of Trade to be imported into this country in abnormal quantities. A rapid decision was, of course, necessary because the threatened tariff had led to a greater quantity of goods being imported than had been customary.

The effect of tariffs in restoring the trade balance cannot yet be estimated, but it should be remembered that this country has long had a very large foreign trade, and the fall in the value of sterling, which acts in the form of a tariff, as well as additional duties which may be imposed, is bound to have a very great influence on the distribution of international trade. Now that the sterling is at a considerable discount in countries on the gold standard, our manufacturers are, in some instances, more favourably placed in regard to exports, but in others a tariff equal to the depreciation has been imposed, which makes the position worse than previous to the depreciation of the £. Further, all goods imported from countries on the gold standard must be paid for at an enhanced price—that is, the discount on sterling must be made good. Thus, the tariff imposed by a depreciated currency is not an unmixed blessing.

Whether the imposition of duties on imported goods will definitely restore our trade balance and operate in the national interest is a question to which none can give an adequate answer. That this country was at one time a firm believer in tariffs is a matter of history. Protection began in the early part of the fourteenth century, while in the fifteenth century the importation of many manufactured articles was definitely prohibited. Tariffs were imposed for many centuries, and during the latter part of the eighteenth century very restrictive measures were adopted to protect home manufacturers. These were continued until about the middle of the nineteenth century, when during a period of about seventeen years protective duties were gradually removed, leaving duties which were applied essentially for revenue purposes. It will thus be seen that the policy of adopting protective measures is not by any means new to this country, and the period during which Free Trade has been operative is short by comparison with that when tariffs were imposed.

In view of the large foreign trade which has been built, and the tremendous influence tariffs will have upon it, great changes in world trade will eventually be manifest, and it behoves the Board of Trade to be especially careful in visualising future possibilities before a protective duty is imposed on articles. In our opinion, tariffs should not operate to benefit primarily any one particular trade or industry, but should be accepted only when their application is definitely in the national interest.

At the same time, we feel that the condition of the iron and steel trade should be given careful consideration. The need for the protection of this basic industry is becoming increasingly apparent, and much dissatisfaction prevails as a result of the impression created by the President of the Board of Trade that imports of iron and steel are negligible in relation to production. Sir W. J. Larke has shown that the low figures obtained by the Board of Trade did not convey full import returns. He supported his contention by facts which indicate that while the import of steel in 1929 represented approximately 31% of home production, the steel imports for October of this year amounted to approximately 61% of home production. Thus, although production in this country has fallen to very low figures, imports of steel have proportionately increased until they are now imported at nearly twice the rate that operated during 1929.

That careful consideration of this problem is necessary is emphasised by the fact that although iron and steel is the finished product of the iron and steel industry, it is the raw material of a wide range of trades, and the necessity of obtaining this raw material at the lowest possible cost facilitates the export of finished articles of which they form a part.

In this way much work is put into the raw material, which has an enhanced value commercially. The trades thus affected have an important influence on the national economic structure, and a hurried decision on this very thorny problem might well have very serious consequences. In spite of the difficulties, however, the problem should be faced and the facts stated, in order that the conflicting interests apparent between producers and consumers of iron and steel may be reconciled and a definite decision of the Government's policy given.

It is rather strange that Great Britain, which for years has been pressing for a reduction of tariffs, with the object of facilitating world trade, should have finally come into line with other nations, and accepted the principle of protection for her industries. All the efforts of her statesmen to effect reductions in the tariffs of other nations have in the past proved abortive, excepting in so far as a compromise was arranged, for which they have been regarded as a means of bargaining between nations. Now that this country has succumbed to what apparently was the inevitable, the rearrangement of world trade that is bound to follow may possibly cause nations to reconsider the whole tariff problem on a wider basis. The *New York Times* apparently grasps the full significance of universal tariffs in saying that if all industries in a country are equally protected they cease to be protected at all in the sense of one having an advantage over the other, and, in the same way, if all nations have what they regard as a perfect system of protection by customs duties, they are in the way to discover that the whole method is a failure and a sham. Thus, it may turn out that the complete triumph of the protective system will be its death warrant throughout the world.

It is an interesting thought that Great Britain, though unsuccessful in removing restrictions on international trade as a Free Trade country, may assist very considerably in achieving this object by her acceptance of protective tariffs. But, meanwhile, it is the duty of the Government to investigate very carefully the difficulties operating against the balancing of our trade, and as soon as they are convinced that the national interests are best served by protecting this or that industry, rapid action should be taken to apply suitable duties to the imported articles involved.

British Standards Institution.

ONE of the most important developments of this century is that of standardisation in industry. Although not by any means a panacea for the industrial depression prevailing, standardisation, properly organised, is an important factor in diminishing the excessive fluctuation of industry, in eliminating much avoidable waste, and in promoting greater efficiency. The main efforts have been directed towards the co-ordination of the requirements of producers and users, through the setting up of standards of quality and performance, with the object of simplifying production and distribution, and in this way bringing about more equity in the purchase and sale of industrial materials and appliances.

At the present time, when the necessity to improve trade is so vital to our interests, it is important that the various trades and industries should unite in the spirit of co-operation to unify, simplify, and modify their requirements by agreement, adopting what is economically best in practice, without any attempt to set up an ideal which might be too costly to adopt. The British Engineering Standards Association has done much valuable work in this direction, but in a somewhat limited field.

During recent years, however, this Association has prepared British standard specifications and established British standards not only for use in the engineering field, but also for a growing range of materials in the building, chemical, and textile industries, and the work done has been fully appreciated.

The need for regularising this extension of the original functions of the Association has been under consideration from time to time, and became imperative when the chemical industry invited the Association to widen its scope to include chemical standardisation generally. The building industry also desired a substantial extension of the work of standardisation within that industry, and urged that the title of the Association should be more in conformity with the wideness of its scope. In addition to the requests of various industries, the desire was expressed at the Imperial Conference, held in 1930, that there should be a single centralised national standardising body in each of the countries forming the British Empire.

To meet the various requests, it has been decided to reorganise the work of this Association into four main divisions of equal standing, responsible for the preparation of British Standard Specifications in the engineering, chemical, building, and textile industries, each of the divisions being under the control of a representative divisional council, and a supplementary Royal Charter has been granted authorising these changes.

In future, the name of the Association will be the "British Standards Institution," and its activities will be under the control of a General Council, which will have under it the four Divisional Councils. The work of the Engineering Division will, as before, be delegated to industry committees dealing with the main branches of the engineering industry, such as civil engineering, mechanical engineering, electrical engineering, etc., and will, of course, for a time represent the larger portion of the Institution's activities.

The great development in the standardising movement which has taken place since the first Committee was set up by the Institution of Civil Engineers in 1901 as the Engineering Standards Committee, is a clear indication that industry as a whole has increasingly recognised the economic value of the work. The term "British Standard" is now registered by the Institution as its standardisation mark.

It should be noted that the Institution is not a profit-making concern, and apart from the grants received from the Government and the amount derived from the sale of its publications, it has to look to the associated industries for the funds necessary to carry on the work. Every British firm in these industries is eligible to become a member of the Institution at a nominal fee, and in their own as well as the national interest they should be associated with this Institution's activities.

The New Cunard Liner.

THE stoppage of the work on the new Cunard liner is regrettable, not only because it affects so many people who are just beginning to appreciate the benefits of employment, but upon all Britishers who are looking forward to the new vessel recapturing the blue riband of the Atlantic. This misfortune will have a depressing effect upon all associated with the construction of the vessel on the Clyde and in other districts where subsidiary work for the vessel has been in progress.

The present monetary position due to world causes is no doubt the primary cause of this unfortunate decision, and the depreciation in the value of securities will have had considerable influence. It might be suggested that the Government could give a guarantee to enable the work to proceed, and, while assistance would undoubtedly be beneficial, it is very questionable indeed whether such a course is open to the Government under present conditions.

The sudden dismissal of all workmen employed on the vessel will have had a paralysing effect upon them, as the prospects of work elsewhere before the New Year are very remote. We hope that necessary money may become available on favourable terms to enable the work to be restarted at an early date.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Jan. 8. Thomas Lowe Gray Lecture by Sterry B. Freeman, C.B.E., M.Eng., M.I.Mech.E. Subject: "Modern Types of Propelling Machinery for Mercantile Marine Use."

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Dec. 17. "The Super-atmospheric Oil Engine," by Harry Hunter, B.Sc.

Jan. 15. "Rivets," by R. Boardman.

INSTITUTE OF ENGINEERS AND SHIPBUILDEKS IN SCOTLAND.

Jan. 12. "Modern Methods of Steel Bridge Manufacture," by J. Thompson, B.Sc.

INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Jan. 12. "Stainless Steel," by J. H. G. Monypenny, F.Inst.P.

LONDON SECTION.

Jan. 14. "X-ray Examination of Alloys," by G. D. Preston, B.A.

NORTH-EAST COAST SECTION.

Jan. 12. "Defects in Non-ferrous Castings," by R. Dowson, S. G. Homfray, B.A., and A. Logan.

SCOTTISH SECTION.

Jan. 11. "Some Properties of Firebricks," by H. C. Biggs.

SHEFFIELD SECTION.

Jan. 15. "Stresses in Metals," by A. Wragg, B.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

LINCOLNSHIRE SECTION.

Jan. 9. "Oil Sand Cores," by B. Gale.

LANCASHIRE BRANCH.

Jan. 9. "Sand Slinging Practice in the Foundry," by A. J. S. Shewan and J. Atchison.

BURNLEY SECTION.

Jan. 14. "High Strength Light Alloys," by W. C. Devereux.

MIDDLESBROUGH BRANCH.

Jan. 8. "The Combining of Metallurgical Knowledge with Practical Foundry Training," by H. Foster.

SHEFFIELD BRANCH.

Dec. 18. "The High-frequency Furnace and its use for Making Steel Castings," by T. R. Middleton.

Jan. 15. "High-strength Light Alloys," by W. C. Devereux.

WALES AND MONMOUTH BRANCH.

Jan. 9. "Balancing the Elements," by F. J. Cook, M.I.Mech.E.

MANCHESTER METALLURGICAL SOCIETY.

Dec. 16. Symposium and Demonstration of "Protective Metallic Coatings," by E. O. Jones at the University.

Jan. 6. "Heat-treatment of Nickel Alloys," by W. T. Griffiths, of Mond Nickel Co., Ltd.

German Impressions of American Rolling Mill Construction

The superiority of American Rolling Mills, in certain respects, was emphasised in an interesting paper presented at the meeting of the Association of German Ironmasters.

AT the general meeting of the Association of German Ironmasters, held at Düsseldorf on November 28, Dr.-Ing. A. Koegel, of Rheinhausen, gave a paper with the above title. He dealt with the developments in American rolling-mill construction and practice, comparing them with the position in Germany and pointing out possibilities of altering the latter.

He dealt first with the manufacture of semi-finished products, in which different drafting is employed in America from that used in Germany. The American practice enables higher outputs to be obtained, which is, however, accompanied by overstressing of the material, evidenced by the formation of cracks. Sometimes a second blooming mill with smaller rolls is placed after the main blooming mill, relieving the latter of some of the work under favourable conditions of use. The pure continuous blooming mill is an exception; on the other hand, the actual mills for the production of semi-finished billets and sheet bars are nearly always built as continuous mills with six to twelve stands, divided into groups of two to eight stands. In the mills for semi-finished products particular care is taken in regard to the surface of the material, especially in the case of steels of special qualities.

The construction and operation of mills for rails and shapes also differs from the German. The new mills no longer have two or three stands alongside each other, but often have an independently working roughing stand with sometimes a finishing stand of the same design. This construction naturally permits the attainment of a high output. Recently there have further been installed many new intermediate furnaces for rail manufacture; these re-heat the blooms coming from the blooming mills for about 15 to 20 mins. before they pass to the rail-mill. These furnaces are said to have contributed very considerably to a reduction of rejections. The production of good material is about 80% in the manufacture of rails, these being still mainly 12 m. long, although in individual cases lengths up to 20 m. are already rolled. Several mills using the principle of the Gray mill are employed for the rolling of broad-flange beams, the newest of which was, until recently, that at Homestead, with an average output of 135 tons per hour. During the past year there has, however, been commenced the construction of a new mill of this type at Chicago, the special novelty of which is that the pinion stand is dispensed with, the top and bottom rolls being separately driven.

In the latest developments of rolling mills for the manufacture of merchant material three directions can be clearly noted: (1) The further development of mills having one or more continuous roughing mills and four to six finishing stands. The finishing mills now have the individual stands built independently and to a large extent fitted with motors having speed regulation. (2) The second type is the so-called zigzag three-high mill or cross-country mill, the characteristic of which is that only one pass is made in each stand, but no tension can arise in the bar being rolled. A natural result of this is that the plant is spread over a large amount of space, and that the installation costs are very high. On the other hand, the advantages of this type are so great from the point of view of rolling technique—increased output, ease of changing rolls, ease of operation and quality—that it has been very widely adopted, especially for materials of special grades. (3) The third line of development is the pure continuous merchant mill with the various stands arranged directly after each other and in which the bar is worked from all sides at the same time (universal mill). These mills are, however, in no way suitable for the production of material on which special demands are made in regard to the rolling. They suffice for the production of ordinary merchant qualities.

The production of the modern merchant mills is from 10,000 to 15,000 tons per month: a yield of less than 90% is unknown.

The efforts to produce a better product have also led to further developments in the case of the wire mills, which are worthy of notice. The 16-stand continuous Morgan mill, with two strands being rolled simultaneously, which was formerly almost universal, has now been abandoned. It is now always carried out with 17 stands, usually divided into two sections in such a manner as to permit the formation of a loop. In the latest design only one strand is rolled in the last four or six stands, two continuous finishing trains being installed for these passes. Under such conditions the rolling speed is increased to about 32 metres per second, which has made it possible to roll 4-cwt. coils without trouble. In the new mills the final temperature of the wire is regulated by the use of water. The removal of the coil of wire has been utilised for heat-treatment by carrying it first through a cooling channel; the value of this is, however, questionable. The production of the wire mills is almost everywhere equal to 95%.

The strip mills have also been developed in several directions in view of the existing requirements. Here mention should first be made of the mills for the production of tube strip: the best of these have an output of 40 to 50 tons per hour. The strip-mills, properly so called, for narrow strip, are either wholly continuous or semi-continuous. For wider strip, over 200 mm. (7⅞ in.) wide, the mills are all fully continuous. The various mills run very fast, up to 15 metres per second, and produce strip which is rolled to much closer limits than in Germany. The most striking advances have been made in the mills for the production of very wide strip up to 1,200 mm. (48 in.), which have been developed from the ordinary strip-mill and are built deliberately to displace the sheet-mill. These mills are naturally arranged as fully continuous with 9 to 11 stands, the necessary blooms being provided by a special blooming mill. The capacity of these mills corresponds to that of the blooming mill, and must not be less than 30,000 tons per month. The final thickness of the hot strip is 1·6 mm. (0·064 in.). It was only possible to secure uniform thickness over the whole width of the strip by adopting the four-high mill for hot rolling. The finished rolled strip is coiled and then goes to the continuous heating plant, after which it is reduced to the thickness of the finished sheet in the adjacent cold-rolling plant, and cut to the lengths required for thin sheets. The subsequent handling is the same as has been usual in the case of thin sheets.

All the plants described above present substantial advances in rolling-mill construction; the superiority of American rolling mills in many respects cannot, therefore, be questioned. In particular, the striving after the production of rolled material of special quality is unmistakable. Since under German conditions the fundamental basis for the building of such rolling mills—the market for the gigantic output—will be lacking for any period within sight, a similar development of mill construction appears to be out of the question here. In regard to details, however, the advances of the American can also be made of service in German mills.

Heat-treating and Forging Some Light Alloys

By W. C. Devereux.

(*Managing Director High Duty Alloys, Ltd.*)

The heat-treatment and forging of Duralumin "Y" alloys, and Hiduminium R.R. alloys was discussed very fully by the author in a paper before the Manchester Metallurgical Society recently, the salient points of which are given in this article.

THE rapid development of aluminium alloys during comparatively recent years is largely due to the remarkable amount of research and experimental work that has been successfully carried out, but the rapid assimilation by many industries of the more important results obtained has materially increased their application to a wide range of high-duty services. The purpose of this article, however, is to deal with Duralumin "Y" alloys and the R.R. alloys, the latter being patented materials developed over a number of years by the Rolls Royce Co., from the points of view of their heat-treatment and forging.

TABLE I.

PERCENTAGE COMPOSITION OF FORGING ALLOYS.

Remainder: Aluminium.

Alloy.	Copper.	Nickel.	Magnesium.	Titanium.	Iron.	Silicon.
R.R. 56	2·0	1·25	0·80	0·08	1·35	0·6
R.R. 59	2·2	1·35	1·5	0·08	1·35	0·8
"Y" alloy	4·0	2·0	1·5		Impurities	
DTD 18 C, known as Duralumin	4·0	—	0·55	Manganese 0·5	"	

All these alloys are obtainable in the extruded, forged, and stamped condition or as sheets, tubes, etc., and their chemical analyses are shown in Table I. A small amount of silicon and iron is always present in the virgin aluminium, indeed the silicon in conjunction with some of the magnesium provides one of the hardening constituents Mg_2Si. In order to provide greater strength and hardness in the "Y" alloy more silicon could be absorbed. The small amount of iron present forms a compound Al_3Fe, which is also a hardening constituent, but attempts to increase the two elements—silicon and iron—in an effort to increase the physical properties are invariably associated with foundry and machining difficulties.

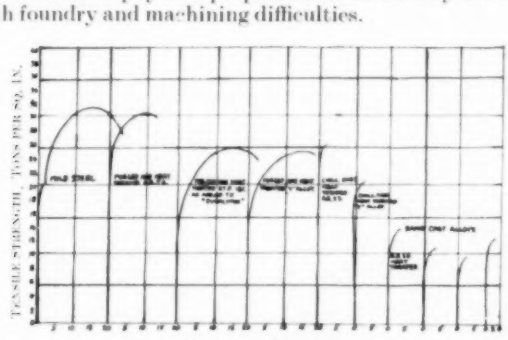


Fig. 1. Load extension curves of the Hiduminium R.R. alloys, compared with mild steel—0.27 C, 0.6 Mn. Brinell 220.—and other light alloys.

Although generally referred to as impurities, silicon and iron are also necessary in Duralumin, to provide two of the hardening compounds. In this instance an increase of silicon, especially if accompanied by a lowering of the manganese and magnesium to the low limit of the specification, makes for easier working, but retards precipitation by natural ageing by several days. An increase of iron, apart from making the material sluggish in the ingot mould, tends to produce a certain amount of brittleness, and is therefore not recommended.

A number of stress strain diagrams of these light alloys is shown in Fig. 1, in comparison with a diagram of a common form of mild steel. The illustration also shows

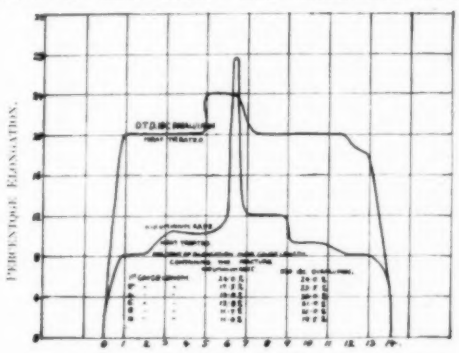


Fig. 2.—Diagram showing distribution of elongation over 14 in.-gauge length of R.R. 56, and D.T.D. 18C.

diagrams of some cast aluminium alloys, but for the purpose of this paper these figures may be ignored. The standard heat-treatment temperatures, which correspond to the properties shown in Fig. 1, are given in Table II.

Some extraordinary differences are indicated in the elongation diagram Fig. 2. This shows the distribution of elongation taken over a 14-in. gauge length of Duralumin and R.R. 56 material. The reason for this phenomena will be apparent as the effect of crystal size and formation is considered; actually, crystal slip takes place over the full length of the bar to a greater extent in the Duralumin than in the R.R. 56. It indicates what is now becoming increasingly well known, that designers must be diffident in taking the elongation figure over the 2-in. gauge length as being a direct measure of the ability of a material to accommodate a local overstress.

TABLE II.

HEAT-TREATMENT OF FORGING ALLOYS.

Alloy.	Solution Treatment.			Precipitation Treatment.		
	Temperature.	Time.	Quench	Temperature.	Time.	Quench.
R.R. 56	530° C.	2 hours	Cold water	170° C.	20 hours	Cold water
R.R. 59	530° C.	2 hours	Cold water	170° C.	20 hours	Cold water
"Y" alloy	520° C.	2 hours	Boiling water	Natural ageing (about 5 days)		
DTD 18 C, known as Duralumin	490° C.	Sufficient for penetration of heat.	Water	"	"	"

This is emphasised in tests carried out on a machine with a reciprocating motion, which produces an effect that may be called deflection fatigue. The machine operates at 42 reversals a minute on test-pieces cut from

German Impressions of American Rolling Mill Construction

The superiority of American Rolling Mills, in certain respects, was emphasised in an interesting paper presented at the meeting of the Association of German Ironmasters.

AT the general meeting of the Association of German Ironmasters, held at Düsseldorf on November 28, Dr.-Ing. A. Koegel, of Rheinhausen, gave a paper with the above title. He dealt with the developments in American rolling-mill construction and practice, comparing them with the position in Germany and pointing out possibilities of altering the latter.

He dealt first with the manufacture of semi-finished products, in which different drafting is employed in America from that used in Germany. The American practice enables higher outputs to be obtained, which is, however, accompanied by overstressing of the material, evidenced by the formation of cracks. Sometimes a second blooming mill with smaller rolls is placed after the main blooming mill, relieving the latter of some of the work under favourable conditions of use. The pure continuous blooming mill is an exception; on the other hand, the actual mills for the production of semi-finished billets and sheet bars are nearly always built as continuous mills with six to twelve stands, divided into groups of two to eight stands. In the mills for semi-finished products particular care is taken in regard to the surface of the material, especially in the case of steels of special qualities.

The construction and operation of mills for rails and shapes also differs from the German. The new mills no longer have two or three stands alongside each other, but often have an independently working roughing stand with sometimes a finishing stand of the same design. This construction naturally permits the attainment of a high output. Recently there have further been installed many new intermediate furnaces for rail manufacture; these re-heat the blooms coming from the blooming mills for about 15 to 20 mins. before they pass to the rail-mill. These furnaces are said to have contributed very considerably to a reduction of rejections. The production of good material is about 80% in the manufacture of rails, these being still mainly 12 m. long, although in individual cases lengths up to 20 m. are already rolled. Several mills using the principle of the Gray mill are employed for the rolling of broad-flange beams, the newest of which was, until recently, that at Homestead, with an average output of 135 tons per hour. During the past year there has, however, been commenced the construction of a new mill of this type at Chicago, the special novelty of which is that the pinion stand is dispensed with, the top and bottom rolls being separately driven.

In the latest developments of rolling mills for the manufacture of merchant material three directions can be clearly noted: (1) The further development of mills having one or more continuous roughing mills and four to six finishing stands. The finishing mills now have the individual stands built independently and to a large extent fitted with motors having speed regulation. (2) The second type is the so-called zigzag three-high mill or cross-country mill, the characteristic of which is that only one pass is made in each stand, but no tension can arise in the bar being rolled. A natural result of this is that the plant is spread over a large amount of space, and that the installation costs are very high. On the other hand, the advantages of this type are so great from the point of view of rolling technique—increased output, ease of changing rolls, ease of operation and quality—that it has been very widely adopted, especially for materials of special grades. (3) The third line of development is the pure continuous merchant mill with the various stands arranged directly after each other and in which the bar is worked from all sides at the same time (universal mill). These mills are, however, in no way suitable for the production of material on which special demands are made in regard to the rolling. They suffice for the production of ordinary merchant qualities.

The production of the modern merchant mills is from 10,000 to 15,000 tons per month: a yield of less than 90% is unknown.

The efforts to produce a better product have also led to further developments in the case of the wire mills, which are worthy of notice. The 16-stand continuous Morgan mill, with two strands being rolled simultaneously, which was formerly almost universal, has now been abandoned. It is now always carried out with 17 stands, usually divided into two sections in such a manner as to permit the formation of a loop. In the latest design only one strand is rolled in the last four or six stands, two continuous finishing trains being installed for these passes. Under such conditions the rolling speed is increased to about 32 metres per second, which has made it possible to roll 4-cwt. coils without trouble. In the new mills the final temperature of the wire is regulated by the use of water. The removal of the coil of wire has been utilised for heat-treatment by carrying it first through a cooling channel; the value of this is, however, questionable. The production of the wire mills is almost everywhere equal to 95%.

The strip mills have also been developed in several directions in view of the existing requirements. Here mention should first be made of the mills for the production of tube strip: the best of these have an output of 40 to 50 tons per hour. The strip-mills, properly so called, for narrow strip, are either wholly continuous or semi-continuous. For wider strip, over 200 mm. (7⅞ in.) wide, the mills are all fully continuous. The various mills run very fast, up to 15 metres per second, and produce strip which is rolled to much closer limits than in Germany. The most striking advances have been made in the mills for the production of very wide strip up to 1,200 mm. (48 in.), which have been developed from the ordinary strip-mill and are built deliberately to displace the sheet-mill. These mills are naturally arranged as fully continuous with 9 to 11 stands, the necessary blooms being provided by a special blooming mill. The capacity of these mills corresponds to that of the blooming mill, and must not be less than 30,000 tons per month. The final thickness of the hot strip is 1·6 mm. (0·064 in.). It was only possible to secure uniform thickness over the whole width of the strip by adopting the four-high mill for hot rolling. The finished rolled strip is coiled and then goes to the continuous heating plant, after which it is reduced to the thickness of the finished sheet in the adjacent cold-rolling plant, and cut to the lengths required for thin sheets. The subsequent handling is the same as has been usual in the case of thin sheets.

All the plants described above present substantial advances in rolling-mill construction; the superiority of American rolling mills in many respects cannot, therefore, be questioned. In particular, the striving after the production of rolled material of special quality is unmistakable. Since under German conditions the fundamental basis for the building of such rolling mills—the market for the gigantic output—will be lacking for any period within sight, a similar development of mill construction appears to be out of the question here. In regard to details, however, the advances of the American can also be made of service in German mills.

Heat-treating and Forging Some Light Alloys

By W. C. Devereux.

(*Managing Director High Duty Alloys, Ltd.*)

The heat-treatment and forging of Duralumin "Y" alloys, and Hiduminium R.R. alloys was discussed very fully by the author in a paper before the Manchester Metallurgical Society recently, the salient points of which are given in this article.

THE rapid development of aluminium alloys during comparatively recent years is largely due to the remarkable amount of research and experimental work that has been successfully carried out, but the rapid assimilation by many industries of the more important results obtained has materially increased their application to a wide range of high-duty services. The purpose of this article, however, is to deal with Duralumin "Y" alloys and the R.R. alloys, the latter being patented materials developed over a number of years by the Rolls Royce Co., from the points of view of their heat-treatment and forging.

TABLE I.

PERCENTAGE COMPOSITION OF FORGING ALLOYS.

Remainder: Aluminium.

Alloy.	Copper.	Nickel.	Magnesium.	Titanium.	Iron.	Silicon.
R.R. 56	2·0	1·25	0·80	0·08	1·35	0·6
R.R. 59	2·2	1·35	1·5	0·08	1·35	0·8
"Y" alloy	4·0	2·0	1·5		Impurities	
DTD 18 C, known as Duralumin	4·0	—	0·55	Manganese 0·5	"	

All these alloys are obtainable in the extruded, forged, and stamped condition or as sheets, tubes, etc., and their chemical analyses are shown in Table I. A small amount of silicon and iron is always present in the virgin aluminium, indeed the silicon in conjunction with some of the magnesium provides one of the hardening constituents Mg_2Si. In order to provide greater strength and hardness in the "Y" alloy more silicon could be absorbed. The small amount of iron present forms a compound Al_3Fe, which is also a hardening constituent, but attempts to increase the two elements—silicon and iron—in an effort to increase the physical properties are invariably associated with foundry and machining difficulties.

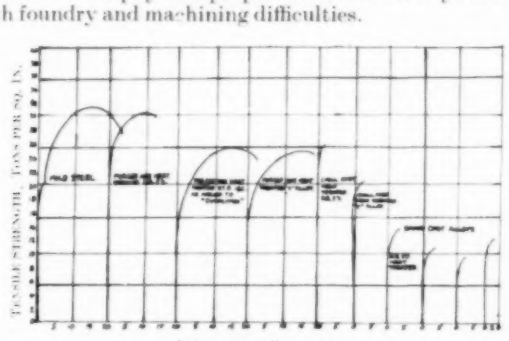


Fig. 1.—Load extension curves of the Hiduminium R.R. alloys, compared with mild steel—0.27 C, 0.6 Mn. Brinell 220.—and other light alloys.

Although generally referred to as impurities, silicon and iron are also necessary in Duralumin, to provide two of the hardening compounds. In this instance an increase of silicon, especially if accompanied by a lowering of the manganese and magnesium to the low limit of the specification, makes for easier working, but retards precipitation by natural ageing by several days. An increase of iron, apart from making the material sluggish in the ingot mould, tends to produce a certain amount of brittleness, and is therefore not recommended.

A number of stress strain diagrams of these light alloys is shown in Fig. 1, in comparison with a diagram of a common form of mild steel. The illustration also shows

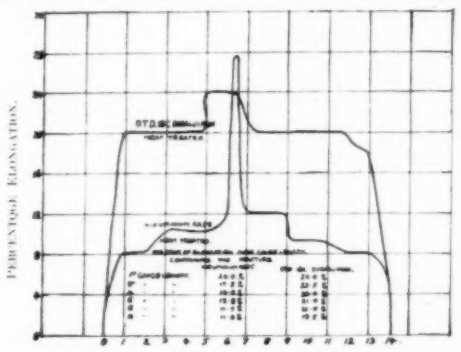


Fig. 2.—Diagram showing distribution of elongation over 14 in.-gauge length of R.R. 56, and D.T.D. 18C.

diagrams of some cast aluminium alloys, but for the purpose of this paper these figures may be ignored. The standard heat-treatment temperatures, which correspond to the properties shown in Fig. 1, are given in Table II.

Some extraordinary differences are indicated in the elongation diagram Fig. 2. This shows the distribution of elongation taken over a 14-in. gauge length of Duralumin and R.R. 56 material. The reason for this phenomena will be apparent as the effect of crystal size and formation is considered; actually, crystal slip takes place over the full length of the bar to a greater extent in the Duralumin than in the R.R. 56. It indicates what is now becoming increasingly well known, that designers must be diffident in taking the elongation figure over the 2-in. gauge length as being a direct measure of the ability of a material to accommodate a local overstress.

TABLE II.

HEAT-TREATMENT OF FORGING ALLOYS.

Alloy.	Solution Treatment.			Precipitation Treatment.		
	Temperature.	Time.	Quench	Temperature.	Time.	Quench.
R.R. 56	530° C.	2 hours	Cold water	170° C.	20 hours	Cold water
R.R. 59	530° C.	2 hours	Cold water	170° C.	20 hours	Cold water
"Y" alloy	520° C.	2 hours	Boiling water	Natural ageing (about 5 days)		
DTD 18 C, known as Duralumin	490° C.	Sufficient for penetration of heat.	Water	"	"	"

This is emphasised in tests carried out on a machine with a reciprocating motion, which produces an effect that may be called deflection fatigue. The machine operates at 42 reversals a minute on test-pieces cut from

1 in. square forged bar, heat-treated to give the specification figure, machines all over and polished to a high finish. The speed was purposely slow in order to avoid shock. The results of these tests are given in Table III., in which

TABLE III.

DEFLECTION FATIGUE RESULTS ON HEAT-TREATED BARS.

Deflection.		Number of Reversals to Fracture.			
Distance from Vertical.	Total Angle.	R.R. 56.	"Y" Alloy.	DTD. 18 C as Duralumin.	Mild Steel Normalised.
½ in.	4° 40"	26,246	20,495	20,771	4,758
⅝ in.	5° 56"	9,820	6,583	7,472	4,990
¾ in.	7° 0"	8,109	6,378	5,093	4,624

Each figure is the average of six tests.

Mild steel takes a severe permanent set from the first bend at each deflection.

it will be seen that the material with the highest elastic limit, although lower on the elongation figures, has come out best.

Confirmation of this is given by P. Ludwick in a paper read before the New International Association for Testing Materials, at Zurich, in September, in which he states "the resistance to alternation stress of metals with polished surfaces is dependent on the resistance to deformation, and not on the ability to undergo deformation. Great resistance to deformation was frequently found in conjunction with high sensitivity under impact."

The results of the mild steel specimen in this test follow the theoretical consideration which shows that aluminium will absorb considerably more energy than steel under the same dynamic load, by virtue of its lower modulus of elasticity, this holding good so long as the stresses are kept below the elastic limit.

Fig. 3 gives the Wöhler fatigue figures for material taken from 1¼ in. square forged bar, heat-treated and machined at the point of maximum bending moment to 0·53 in. diameter, the effect of various annealing temperatures on the maximum stress and 0·1% proof stress on the materials under discussion is shown in Fig. 4, while Fig. 5 gives the effect on the Brinell hardness and elongation.

For application of these materials at elevated temperatures a selection must be made. "Y" alloy or the R.R. group respond well at such temperatures, the copper, and particularly the nickel in the case of "Y" alloy, assisting their physical properties, while, in the R.R. alloys, in addition to the copper and nickel, the iron forms a compound Al_3Fe, which, in addition to increasing the heat resistance, prevents growth and stabilises the alloy against natural ageing.

A chart showing the effect of temperature on the ultimate strength is given in Fig. 6. The test-pieces being pulled at temperature, after soaking for a period of 30 mins. at the temperature. The effect of elevated temperature on the Brinell hardness, together with the recovery value after cooling, is shown in Fig. 7; the tests in this case are also taken at temperature, after the specimen has been soaked for 30 mins. These tests were carried out with a 10 mm. diameter ball and a load of 1,000 kg.

The English aircraft industry almost invariably use a forged piston, the material for which should have a low frictional resistance, in addition to good physical properties at elevated temperatures. An attempt to measure this has been made on a machine designed and made by the

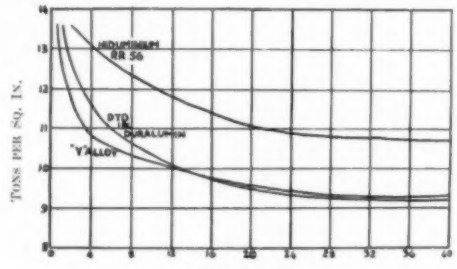
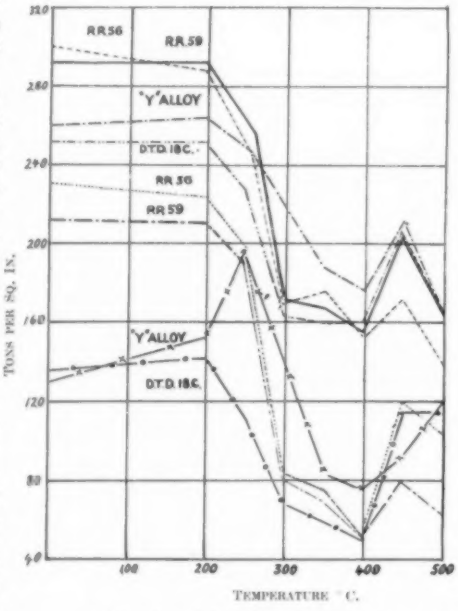
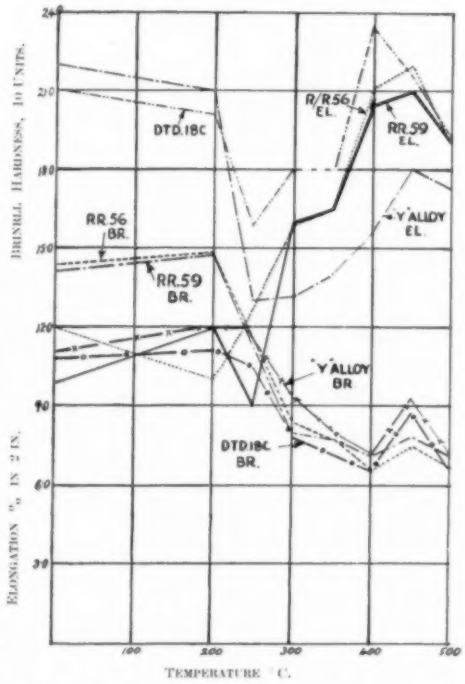


Fig. 3.—Fatigue curves on forged bars 1¼ in. square, heat-treated. Wöhler type—Amoler machine

Rolls Royce Laboratories, in which a chuck, which holds four test-pieces, is rotated through a swivel joint connected to the shaft of the motor. A load of 100 lb. per sq. in. is applied to the test-pieces, which run on a 0·5 carbon steel disc (Spec. No. B.E.S.A. S 70) in a bath of P 4 oil, heated to the desired temperatures. The chuck rotates at 545 r.p.m., and the friction is measured by amperes. The results of this test are given in Fig. 8. The R.R. 60 material referred to on this graph is exceptionally good for





Figs. 4 and 5.—The effect of temperature on the physical properties of R.R. 56, and R.R. 59, "Y" alloy, and D.T.D. 18C. Tests carried out on 1¼ in. square forged bar, heat-treated. Test pieces soaked at various temperatures for two hours, and allowed to cool in air, then machined to 0.564 in. diameter, and tested cold.

frictional properties, the other physical properties, at normal and elevated temperatures, being similar to those of the R.R. 56 alloy, excepting that higher Brinell hardness values are registered.

The forging of aluminium alloys is a job for the specialist, and it does not follow that a firm, capable of making good steel stampings can necessarily make good aluminium alloy stampings. Much more care and control is necessary in their production. In dealing with forgings direct from the cast ingot, the policy of High Duty Alloys, Ltd., is to cut and examine the head of one ingot in each melt for small stampings, and to examine the cut ingot for each stamping

over 10 lb. in weight. Macro sections of good and bad ingots are reproduced in Fig. 9, from which it will be seen that (*a*) would be rejected for porosity and pin-holes; (*b*) would give trouble by cracking along the grain boundaries during forging operations; (*c*) would perhaps give internal cracks due to the varying plastic strength of some large crystal giving way, throwing excessive work on to other smaller crystals, causing local breakdown. The ideal, of course, is such a structure as shown at (*d*), which from the first blow gives no trouble, although possibly for rolling operations a structure such as at (*c*) would work quite easily.

The ingots should be soaked from 6 to 8 hours before commencing working. Duralumin at a temperature of 460° C., and "Y" alloy at 470°–480° C., but R.R. 56 at a temperature of 480°–500° C. The first forging operation should not be carried on with the material much below 400° C. Following the first heat or so, soaking is not necessary except to bring the material up to temperature throughout the piece. After putting approximately 50% of forging work into the piece, stamping operations can follow. The effect of forging at too high a temperature, but not necessarily quite at the melting point of the eutectic, is shown in Fig. 10 at A.B. Duralumin will break down in such a way at 10° C. to 15° C. below "Y" alloy, and 20° to 30° C. below the R.R. 56 material, doubtless because the eutectic forms a larger proportion of the material with a lower melting point. The effect of forging at too low a temperature in the early stages is to crack the material usually from the edges or corners. The effect of over-forging a square ingot at the start, creating a wedge formation from the sides and also resulting in piping of the centre, is shown at C, Fig. 10.

In the case of Duralumin the stamping operations are carried out with the work at a temperature of 450°–460° C., with "Y" alloy and R.R. 56 at 480°–500°—a slightly lower temperature if the dummy is not well supported in the die at the start of stamping, but as the dummy begins to fit the dies then it is safe to work to the maximum temperature. The shape and size of the dummy is of great importance, in fact so important is this considered at the works of High Duty Alloys, Ltd., that a special inspection is made at the dummy stage. The effect of using a correct and incorrect dummy size is shown in Fig. 11—(*a*) has split through the flash-line, due to the use of too large a dummy. This would be easily detected, but there is an intermediate state, as at (*b*); here splitting has not occurred, but a distinct plane of weakness will be noted along the flash-line; (*c*) is made from a correct dummy, and, providing all dummies are of the same shape and size, with the temperature of stamping correct, then consistently good results will be obtained. The temperature is particularly mentioned because the bad effects shown can also be produced by working at a temperature bordering on the melting-point of the eutectic.

It is futile to attempt to correct the effect of an offset die by resetting the die and again stamping the offset piece; invariably this results in fibre shear along the flash-line, and owing to the seemingly amorphous adherence of the material it is sometimes not detected until a subsequent machining operation discloses the crack. The whole success of the stamping and forging operation lies in the absolute adherence to the rules set down and in adopting a fool-proof system of control of temperature and operations in the work.

For reason of economy it is sometimes preferred to stamp out of extruded bar instead of forged bar, and a few hints on where to look for defects and how to work from extruded material will be of value. The temperature will be the same as that given for forged bar, but soaking should only be long enough for the temperature to penetrate through the piece. A common defect in extruded bar is due to the slipping of the core of the ingot at speeds varying from the outside, during the extrusion operation. This may be detected by cutting the extruded bar and micro-etching the section, the appearance being shown in Fig. 12. The bar should be cut at least 1 ft. from the tag-end, as invariably the defect is found at this end.

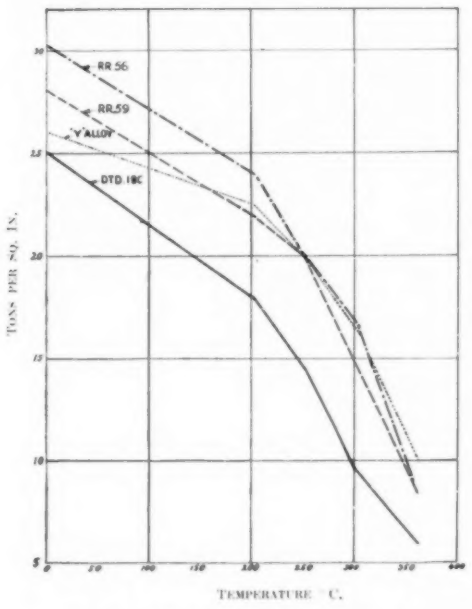


Fig. 6.—The effect of temperature on tensile strength of R.R. 56, R.R. 59, "Y" alloy, and D.T.D. 18C. Forged bar heat-treated.

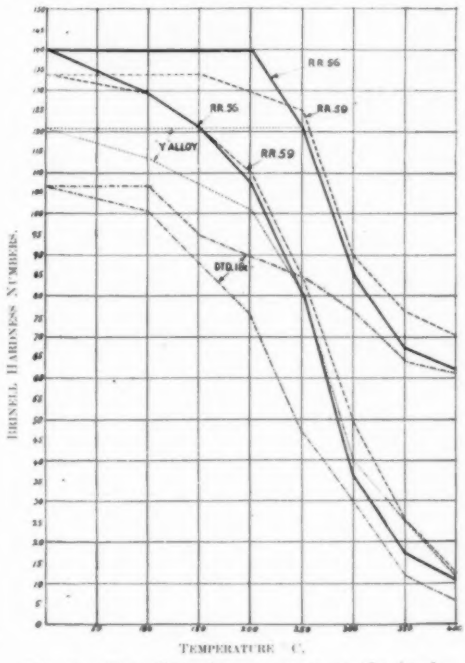


Fig. 7.—The effect of temperature on the hardness of R.R. 56 and R.R. 59, forged heat-treated bar compared with "Y" alloy and D.T.D. 18C., showing hardness at temperature, and recovery value after cooling in air.

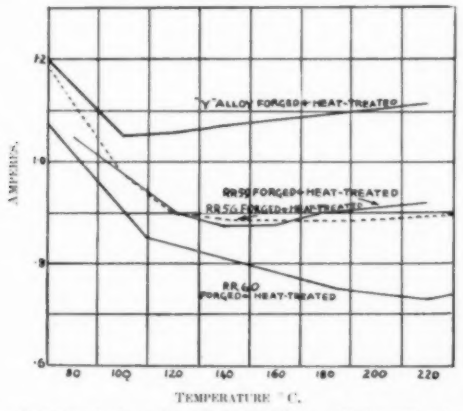


Fig. 8.—Friction tests on forged piston alloys. Dial reading in amperes gives relative friction.

The plastic deformation of the material during extrusion, if done at a certain temperature and time, is such that subsequent heating for a length of time will cause growth of the crystal, therefore in stamping from extruded bar the length of soaking should be as short as possible, to avoid such defects as shown in Fig. 13, in which (*a*) shows

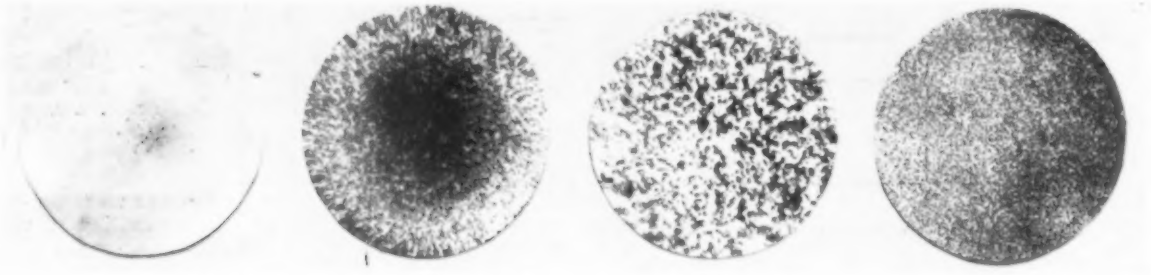


Fig. 9.—A—Porous central pipe. B—Coarse columnar crystals. C—Coarse equi-axed crystals. D—Satisfactory structure.

connecting rod section with mixed size crystals; (*b*) with all large crystals, and (*c*) with correct macro section. This phenomenon is apparent in all extruded aluminium alloy sections, whether duralumin "Y" alloy or R.R. 56; of the connecting rods shown one is "Y" alloy and one R.R. 56. To measure the effect of this variation of crystal size, the rod shown at (*a*) was cut up to get a test-piece from the large crystal portion, and one from the small crystal, these test-pieces being 1/50 sq. in. in area, and pulled on a tensometer machine. The broken test-pieces are shown in Fig. 14; it will be noted how the test-piece with the large crystal has pulled out and the other with finer grain has necked at the break. This accounts for the difference in elongation values, each large crystal having slipped throughout the whole length of the test-piece, whereas the finer grain piece only round the break. The figures are given in Table IV. This crystal growth can be accelerated by temperature and working, as will be seen in Fig. 15, which shows several pieces of material from the same forged bar all cut near to each other, while Fig. 16 shows a similar effect on extruded bar. It is of little value giving the defect unless information is given on how to avoid or correct it, but before discussing this it may be interesting first to see the influence of such growth on the actual physical properties. Test-pieces were cut from the same piece of extruded bar, the crystal size in some being purposely enlarged. Tensile and fatigue tests were taken on both the small and large grain size of the material. A few of these test-pieces are shown in Fig. 17, but it must be remembered that a different plane of the crystal is shown to that which has been shown in cross-section, and in the connecting rod already discussed. The crystal size looks very much larger because the elongated plane is shown. It is of interest to note the way these large crystals have stretched on the tensile test-pieces: this accounts for the higher elongation value of the test-piece with large crystals.

The effect of crystal size on the properties of extruded bar is shown in Table V. Note the lowering of the proof stress and elastic limit with the increase in size of the crystals, whilst the ultimate stress is not so noticeably affected.

With regard to the influence of this crystal growth on the fatigue value; tests were taken on a Wöhler type machine, with the size test-piece already described. The first test was arranged by loading to ± 10·3 tons per sq. in. for 20,000,000 reversals, and increasing the load to ± 10·8 tons per sq. in. The small size crystal ran the 20,000,000 at ± 10·3 tons per sq. in., and then for 6,700,000 reversals at ± 10·8 tons per sq. in.; whereas the large crystal pieces only ran for average 4,000,000 reversals at ± 10·3 tons per sq. in. Several tests gave approximately the same figures. An attempt was then made to test the actual lowering of the fatigue value by running test-pieces until the break and checking them, until 60,000,000 reversals was reached. It was found that the large crystals have the fatigue value of ± 9·1 tons per sq. in., against ± 10·5 tons per sq. in. for the small crystal pieces from extruded bar. These tests show that extruded bar of perfect structure has a fatigue limit about ± 0·5 tons per sq. in. lower than that of forged bar. If this crystal growth is to be prevented from forming when stamping from extruded bar, precautions must be taken to soak the bars for dummying just sufficient to heat them through. The extruded bars may be slightly forged before dummying at a temperature of between 250° and 300° C., or, when the stamping is almost down to size, the final stamping blows carried out at this low temperature. These precautions are not necessary when working from forged bar which has been forged in accordance with the method previously

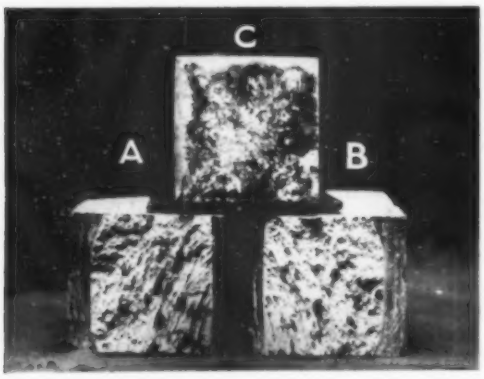


Fig. 10.—Effect of forging at too high a temperature is shown at A and B, while the effect of over-forging is shown at C.

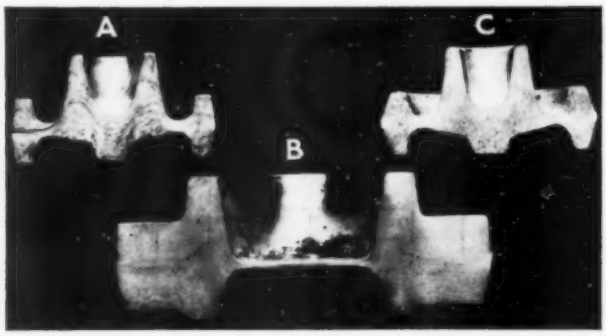


Fig. 11.—Effect of using correct and incorrect dummy size: A—Shows split through flash-line, as a result of too large a dummy. B—shows an intermediate state in which, though splitting has not occurred, a distinct plane of weakness is seen. C—is made from a correct dummy.

described for dealing with forging from the cast ingot material.

It is not proposed to discuss the theory of heat-treatment of aluminium alloys—Hanson, Gaylor, Dix, Archer, and others have dealt fully with this subject,—but rather to confine myself to the practical side of the subject. The heat-treatment best suited for the materials under discussion has been given in Table II., but precautions are necessary according to the type of work to be treated. Thus, for instance, it is not wise to place large solid work, or work with heavy changes of section, into a furnace that is up to temperature, as cracks are likely to develop, due to strain being applied to the cold portion as a result of rapid heating of other parts of the forging or stamping.

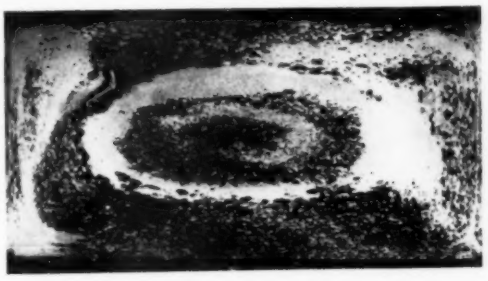


Fig. 12.—Section of extruded bar showing a common defect due to the slipping of the core of the ingot during the extrusion process.

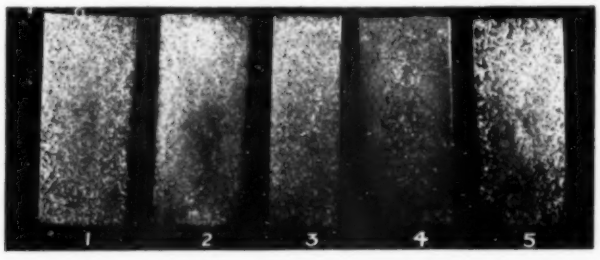


Fig. 15.—Sections showing effect of temperature on crystal growth of forged bar: (1) 1 hour, 530° C. quenched; (2) 2 hours, 530° C. quenched and aged; (3) 2 hours, 490° C. quenched; (4) 12 hours 490°-500° C. quenched and aged; (5) 24 hours 490°-500° C. quenched and aged.

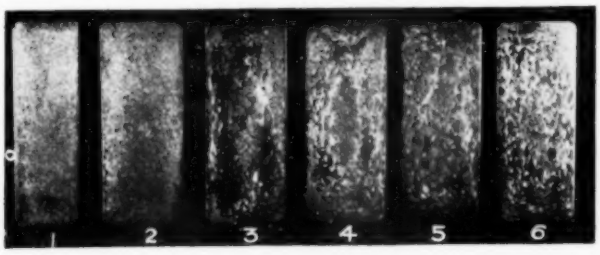


Fig. 16.—Sections showing effect of temperature on crystal growth of extruded bar: (1) 1 hour, 530° C. quenched; (2) 2 hours, 490°-500° C. quenched; (3) 12 hours, 490°-500° C, quenched; (4) 12 hours, 490°-500° C, quenched and aged; (5) 24 hours, 490°-500° C, quenched; (6) 24 hours, 490-500° C. quenched and aged.

A good method is to warm the forging thoroughly before placing it in the hot furnace. A salt bath or electric furnace are both satisfactory for heat-treatment. Personally, I prefer to use the salt bath, as, providing it is well designed and sufficiently large, it is, in my opinion, more easily controlled, and the variations are not so great. It must be remembered that the tolerance for heat-treatment of aluminium alloys is small. In quenching "Y" alloy it is necessary to use boiling water if cracking is to be prevented, but Duralumin and R.R. 56 may be quenched in water at between 65° and 80° C.

Fig. 14.—Test pieces which show that material with large crystals pulls out, while those with finer grain have necked at the break.

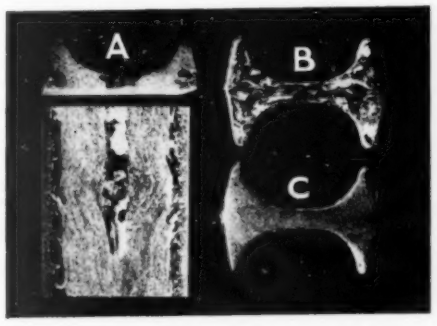


Fig. 13.—Connecting-rod section with mixed size crystals at A, all large crystals at B, and correct macro section at C.

The various specifications issued for light alloy forgings and stampings do not assist one in checking the material

TABLE IV.

Part.	Yield Point, Tons per Sq. In.	Maximum Stress, Tons per Sq. In.	Elongation on $\frac{1}{2}$ in. %	Reduction of Area, %
Coarse crystal	15·0	24·5	22	33
Fine crystal	17·0	24·1	18·0	20

TABLE V.

EFFECT OF CRYSTAL SIZE ON PHYSICAL PROPERTIES OF EXTRUDED R.R. 56 BAR 2½ IN. × 1½ IN.

BARS CONSISTING SOLELY OF LARGE CRYSTALS.

Each Figure is the Average of Six Tests.

	0·1 Proof Stress, Tons per Sq. In.	Yield Point, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation on 2 in.	Brinell.
Longitudinal ...	15·0	19·0	24·5	25	138
Transverse	—	19·0	25·0	14	138

Wöhler fatigue figures, 10·3 tons per sq. in. ..... (2·2 million reversals, (5·8 " "

Fatigue limit by deflection method, 9·75 tons per sq. in.

BARS CONSISTING SOLELY OF SMALL CRYSTALS.

	0·1% Proof Stress, Tons per Sq. In.	Yield Point, Tons per Sq. In.	Ultimate Stress, Tons per Sq. In.	Elongation on 2 in.	Brinell.
Longitudinal ...	22·0	26·0	29·0	11·0	138
Transverse	—	26·0	29·5	8·0	138

Wöhler fatigue figures, 10·3 tons per sq. in., 20 millions; unbroken, reloaded to 10·8 tons per sq. in., 6·7 millions.

Fatigue limit by deflection method, 10·75 tons per sq. in.

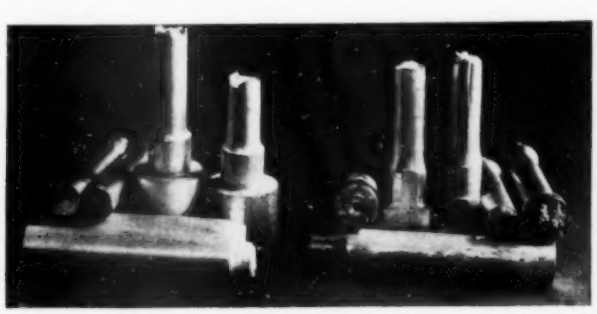


Fig. 17.—Some test peices taken from extruded bar. It will be seen that those with larger crystals have stretched, which accounts for the higher elongation value of the test piece with large crystals.

for overheating. The specification for forgings requires test-pieces to be cut from the piece for longitudinal and transverse directional tests, and often the test has to be taken in a direction that cannot be said to be longitudinal or transverse. In any case, the figures given in the specifications are too low to detect any overheating.

TABLE VI.

OVERHEATED BARS.

"Y" Alloy 2 hours at 550° C. Quenched in boiling water.

Duralumin, 1 hour at 530° C. Quenched in cold water.

	0.1% P.S. Tons per Sq. In.	Yield, Tons per Sq. In.	Ultimate, Tons per Sq. In.	Elongation, %	R. of A. %	Hardness No.
"Y" alloy ...	12·6	16·0	24·8	22·0	30·52	90
Duralumin	10·5	13·3	22·0	25·0	24·48	98
		Same bars—correct heat-treatment				
"Y" alloy ...	13·0	16·2	25·2	21·0	27	114
Duralumin	13·6	14·8	25·2	24·0	29	110

There is a point where the overheating is such as to destroy the quality of the material, and yet the physical properties called for in the specifications will be exceeded. In my opinion, it is much better to have a separately forged test-piece from the melt of the material from which the stampings or forgings are made. This test-piece should be forged to a uniformly standard section, say, 1¼ in. square. The figures for the specification should be based on this test-piece because they can be regulated with great accuracy. This test-piece should be secured in some way to the forgings under test, and should follow them through all their various temperatures, soakings, and quenchings. Tests taken on this piece, together with a twisting test, would quickly detect any overheating.

Firms specialising in the manufacture of such stampings would have no difficulty in preventing overheated work from leaving their works. The practice at the works of High Duty, Ltd., may be useful as a guide. All heat-treatment furnaces are coupled to automatic regulators, and are also connected to automatic recording pyrometers,

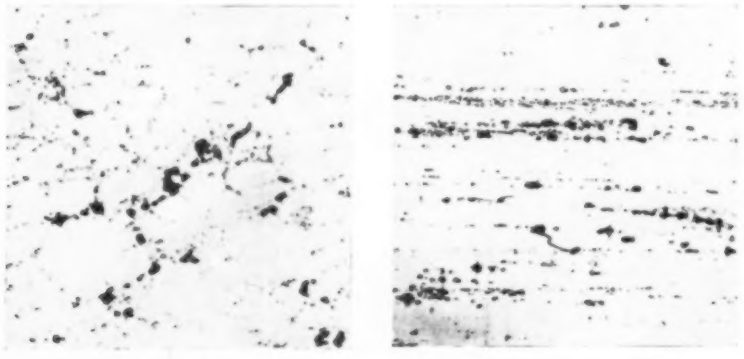
D.T.D. 18C. "Y" ALLOY

Fig. 19.—*Strip* 1 *in.* × ¾ *in., twisted cold, to show whether the material has been overheated.*

as one would imagine would occur with material so maltreated. In any case, the test is too lengthy for adoption in a production works such as the average stamping works or foundry, but it is of interest to note that burnt "Y" alloy, shown in Fig. 18, ran with ± 7·5 tons per sq. in. for 13,000,000 reversals unbroken, a further test with ± 8·96 tons per sq. in. for 4,013,400 reversals and broke, whilst a third test with ± 8·5 tons per sq. in. remained unbroken after 20,000,000 reversals. A test which does immediately tell one of the evidence of overheating is to twist some of the material in a vice. Fig. 19 shows both Duralumin and "Y" alloy so twisted, the burnt piece withstanding hardly any stress before it fractures without twist, whereas exactly similar material, which has not been burnt, will twist more than 180°.

The use of aluminium alloys as forgings and stampings has increased in the last two years beyond the wildest dreams of those responsible for the development of these materials, and their application in the future is very encouraging, but only by extreme care in the manufacture and in the applications will development really succeed.

I do hope that the few notes and small work I have here brought to your notice will do some little to assist those working in this field, and to encourage them to take all necessary steps to see that only the best of material reaches the finished part.



"Y" ALLOY. D.T.D. 18C AS DURALUMIN.

Fig. 18.—*Microphotographs of forgings overheated in heat-treatment* × 100 *diameters.*

while, in addition to the physical tests called for on the specification, a micro-examination is made of each batch of forgings heat-treated.

The above remarks on testing will be found interesting after an examination of the figures in Table VI, which are overheated forged test-pieces, while Fig. 18 shows microphotographs of "Y" alloy and Duralumin, which have been seriously overheated. A comparison of the results of tests on overheated materials with those correctly heat-treated, given in Table VI., will indicate the need of temperature control; but there is a stage in the overheating of the material at which it is difficult to detect overheated material on the static physical properties. The Wöhler fatigue test of a material will not always find this overheating, the drop in fatigue is not so much

Safer Mine Conditions and Increased Efficiency in Recovery of Minerals Stressed.

The incessant campaign for safer conditions in the mineral industries conducted by the United States Bureau of Mines was greatly stimulated in 1931 by the fact that the accidental death rate in the mines for the fiscal year was one of the lowest on record, states Scott Turner, Director of the bureau, in his Annual Report to the Secretary of Commerce. In the first half of 1931 only three major explosions, exacting 41 lives, occurred in the bituminous coal mines of the United States. None occurred during the months of February, March, April, May, and June. An outstanding accomplishment of the bureau was the giving of 112,220 full courses of training in first-aid or mine-rescue instruction to mineral workers.

The bureau was notably successful in the study of processes for increasing the recovery of metals and lowering operating costs during a period of low prices for metals won to a great extent from low-grade ores. Among the more significant of these investigations was that culminating in the discovery of a process for the reduction of zinc oxide by methane or natural gas, which is expected to have far-reaching results.

Recent Developments in Iron and Steel

By J. W. Donaldson, D.Sc.

Steady advance has been made, not only in more efficient manufacture and in improvements, both in working and fabrication, but also in the large amount of investigation and research work on physical and other properties.

DURING the past year there have been no outstanding developments in the metallurgy of iron and steel. Steady advance has been made, however, when one considers the economic position of the industry both at home and abroad, not only in more efficient manufacture and in improvements both in working and fabrication, but also in the large amount of investigation and research work on physical and other properties.

The work of the two Committees originally set up by the Iron and Steel Institute continues under the auspices of the Iron and Steel Industrial Research Council. The Committee dealing with the heterogeneity of steel ingots has issued no report this year, but investigations have continued on a large number of ingots manufactured under carefully controlled conditions, partly in the works and partly in experimental furnaces. A discussion of the structures of these ingots will form the basis of the next report, which it is hoped will be available early next year. Work on the thermal properties of ingot mould irons carried out by the British Cast Iron Research Association will also be included in this report.

The first report of the Corrosion Committee was issued in May, and dealt principally with the correlation of knowledge and data concerning corrosion. A considerable part of the report was devoted to a critical discussion of the replies received to the Committee's questionnaire circulated to producers and consumers of iron and steel, in order to obtain their experience on the corrosion of those materials, with particular reference to the influence of copper additions on the corrosion resistance of ordinary mild steels. Experimental details were also given of the Committee's field tests on the corrosion of ordinary structural mild steel with or without copper additions, and of independent laboratory tests, from the results of which it is hoped to obtain a definite correlation between field and laboratory tests for practical purposes. Further work is being undertaken by this Committee, in which steels, both plain and alloy, made by various processes—open-hearth, Bessemer, and electric furnace—are being tested under varying climatic conditions over a prolonged period. Those steels, with surfaces prepared in various ways, are exposed at seven stations in Britain and at five stations overseas, with a view to ascertaining not only the effects of different atmospheres at home, but also of tropical atmospheres, both dry and humid. It is hoped from the results of such tests that definite and useful data will be obtained which will result in a better understanding of the various phenomena connected with the corrosion of iron and steel, and will have practical results in preventing or retarding such corrosion.

A somewhat similar type of report has just been issued by the Steel Structures Research Committee of the Department of Scientific and Industrial Research. This first report deals with investigations into the practice of the design and construction of steel-frame building, and compares British with foreign practice. The various points investigated include the loads carried by floors in offices, stress in the steel framework of modern buildings, and welding in steel structures. It also recommends a code of practice for the use of structural steel in building. As research work in structural steel has been somewhat neglected, the issue of such a report giving the collected data available, and the fact that experiments, both under laboratory and full-scale conditions, are being continued, should be of considerable value to the makers and users of structural steel, and should stimulate the use of steel as a building material.

Manufacture of Iron and Steel.

In the production of iron, developments have taken place recently in the enlargement of blast furnaces both in America and Germany. In the United States existing units have been enlarged by increasing the hearth and bosh sections without materially increasing the height or top diameter, and outputs up to 1,000 tons per day have been attained. The development of similar furnaces in Germany has been attained, not by increasing the hearth area, but by improvement of the furnace lines and the use of coarser raw material, which permits of large volumes of air being blown at very low pressures. It would appear that the trend of future development in the 1,000 to 1,200-ton furnace should be along both lines together with improvements in the existing auxiliary equipments (hot-blast stores, etc.), which at present account for some of the uneconomical practice in large units. In Britain the largest blast furnace built so far has just been constructed at Dagenham, and is designed to produce 500 tons of pig iron per day.

In steel production, interest continues to be focussed on the commercial application of the coreless induction furnace. In the manufacture of special alloy and heat-resisting steels of high-class tool steels, and of low-carbon steels and alloys, the use of high-frequency steel furnaces has been established. Progress continues to be made with such furnaces in the refining of steel in basic-lined furnaces by slag reactions similar to those used in air furnaces, the refining operations being extremely rapid owing to the circulation of the metal due to electrical forces. So far, the size of high-frequency furnaces have been limited to an output of approximately 1 ton or 1,000 kgs. per hour, but it has been stated that there appears to be no technical difficulties in the construction of 5 to 15 tons capacity furnaces, although progress to such large units will necessarily be slow owing to economic considerations. Developments in this method of steel making and of steel refining will depend largely on the cost of power, but indications are present that where high quality of steel is desired, produced rapidly under satisfactory control, this method shows undoubted advantages, and will make considerable progress in the near future.

Treatment of Iron and Steel.

In the after-treatment of steel the application of the electric furnace for high and low-temperature annealing is becoming of increasing importance. In the heat-treatment of castings, and in carburising and nitriding, the use of electric regenerative, vertical, and rotary hearth furnaces has become of importance, particularly in the automobile and allied industries, and many such units have been installed recently. Such furnaces, owing to the correct disposition of the heating elements, give uniform temperatures up to 1,000° C., and temperature is accurately controlled. Steady and rapid progress in the use of such furnaces will continue, provided low operating and maintenance cost can be secured.

The rapid development in the hardening of steel by nitrogen, since its discovery by Fry, has given rise to many investigations dealing with the process. During the past year important papers by Grossman, Guillet, and Eilender and Meyer have been published. In the first paper the author deals with recent developments in the nitriding process, considers and substantiates most of the eleven claims for the process originally classified by Fry, and also discusses the mechanism of the process. Guillet briefly reviews the process, and gives a list of applications for

nitrided steel. Both authors consider that the presence of aluminium is essential in nitriding steels, and give the maximum hardness attainable as 1,100 to 1,200 Brinell, although Grossman considers such high hardness is not obtained in commercial practice, and is not required, a hardness of 800 to 900 being adequate. Eilender and Meyer give a first report on a series of nitriding investigations carried out on electrolytic iron, 4 carbon, 7 chromium, 6 molybdenum, 6 aluminium, and 5 vanadium steels, and discuss the mechanism of hardening and the influence of such hardening on the various types of steel. An interesting paper from the productive side, giving a detailed explanation of the nitriding process was given by Cunningham and Ashbury at the recent meeting of the Iron and Steel Institute.

The influence of high-frequency oscillations on specimens undergoing the nitriding process has been the subject of researches by Mahoux, who has shown that by such treatment greater depth of penetration is obtained, that the toughness of the core is improved, and that there is greater skin hardness. Steels experimented with included nickel-chrome-molybdenum steel, austenitic valve steel, chromium-plated mild-steel bars, in which as a result of the high-frequency oscillations the chromium penetrated the steel and did not peel, and cast iron, the surface of which was decarbonised and covered with a layer of powdered carbon. Investigations are being continued, and such a method of treatment should be of industrial application in the near future, when it should prove of considerable value in the aircraft and automobile industries for valves and other heat-resisting parts.

The hardening of metals by rotating magnetic fields has also been investigated by Herbert. Work-hardened material which shows an increase of hardness on ageing has this increase in hardness accelerated by magnetic treatment, and quenched material which has been aged shows a series of increasing hardness fluctuations after low-frequency magnetic treatment and ageing. From the results of such experiments it is claimed that the treatment is applicable to the hardening of any type or design of tool, and that the treatment occupies not more than a few minutes at temperatures not exceeding 200° C. Further investigations have shown that the periodic fluctuations of hardness produced can be arrested at any selected phase of the treatment by magnetic stabilisation, which is a point of considerable importance in producing stability.

When considering the treatment of steel, reference must also be made to the continued progress in the manufacture of solid steel drums for high-pressure boiler work. Such hollow forgings, where the drum ends are closed in the forging process, so that the entire drum is a complete shell and the only joints are at the manhole doors, are now being made increasingly in larger sizes with complete success. Hollow forgings are also being increasingly used in oil-cracking plants and in chemical plants.

Constitution and Properties.

In the development of steels and alloys for heat-resisting purposes progress continues to be made. At a joint meeting of the American Society of Engineers and the American Society of Testing Materials held at Chicago in June, various papers were submitted dealing not only with the properties of such materials, but also with their requirements for various industrial purposes. As a result of these papers and their discussion, the trend of future development was indicated, and the qualities and properties required, if such steels and alloys are to be of industrial importance. In this field of research, investigations carried out at the National Physical Laboratory by Jenkins and Tapsell were submitted at the Spring meeting of the Iron and Steel Institute. The favourable resistance of a 30% nickel, 30% chromium, 35% iron, and 4% tungsten alloy to creep at 800° C., indicated by previous experiments, lead to further experiments to determine the influence of various additions of carbon and silicon. In the series of alloys prepared the greatest resistance to prolonged stress at 800° C. were obtained in the alloy containing 15% chromium, 1% silicon.

In alloy steels for general engineering and other purposes, and in stainless steels, no outstanding discoveries have been made during the year, but improvements continue in the technique employed in their manufacture, and in their after-treatment and fabrication. Their use has also been extended in many branches of industry. In this respect, special mention might be made of the copper-content steels, which are being increasingly used on account of their corrosion-resisting properties. Recent work by Nehl on the mechanical properties of those steels has indicated a large field for future investigations.

During the year many important researches have been published dealing with constitution and physical properties of iron and steel alloys. Among those there is an interesting research carried out by Hankins and Becker on the fatigue resistance of spring steels. The results of this investigation shows that surface decarburisation is a most important factor in the low-fatigue resistance of unpolished spring steels, and further experiments are being undertaken to determine whether a carburisation process would result in improving the fatigue resistance of unmachined, hardened and tempered spring plates and forgings.

X-ray investigations continue to play an important part in these researches. Professor Westgreen, in a paper published towards the end of last year, and also in a paper at Zurich in September, indicated the great value of such a method of research, and stated that it should be more widely used than at present. Progress also continues to be made in the application of the X-rays to the study of the internal structure of metals and alloys for commercial purposes, and indications are present that radiographic installations will be established at various centres in the near future. A new method of radiographic inspection has recently been adopted in the United States Naval Research Laboratory by means of gamma rays from either radium or radium emanation. The advantages claimed for this new method are greater simplicity in operation, greater penetration, and more satisfactory results on irregular sections, while the disadvantages are longer exposure times, and lack of general availability of radium.

An event of first importance in the testing of materials was the first Congress of the new International Association of Testing Material at Zurich in September. At the Metal Section of the Congress were discussed such subjects as X-ray examination, metallography, high temperature testing, testing of cast iron, and fatigue, and notched-bar impact testing. Distinct progress was made in international agreement regarding the testing of cast iron and notched-bar impact testing, particularly in the case of cast iron, where the wide divergence in views between British and French engineers and metallurgists was considerably narrowed and almost complete agreement reached. The next International Conference is to be held in London in 1935, under the presidency of Dr. Rosenhain.

Transactions of the Institution of Engineers and Shipbuilders in Scotland.

VOL. LXXV., Part II.

Considerable interest has been shown in the paper on "Parallel Performances of Sister Ships," presented before the Institution by F. G. Brownlie, according to the discussion resulting which is published in this part of the Transactions, and the reply of the author should prove most informative to those who have read his paper. The paucity in this country of publications on time study has caused Sam Mavor to present a paper on "Time Study" in Engineering," in an endeavour to focus attention on the subject. This paper, together with a very full discussion, is published in this issue, as also is a paper on "Oil Tanker Construction," by E. F. Spanner.

Stayrods and Firebox Plates*

English and German Experience of Copper.

By R. Kuhnel.

The author discusses the occurrence of cracks and fractures in stayrods, the tearing of firebox flanges, the wastage of stayrods and fireboxes, and their probable causes.

IN Europe copper is regarded as by far the best metal for locomotive stayrods and fireboxes. Nevertheless, under modern conditions it is by no means the ideal material for the purpose, and it is necessary to look for the inherent faults and to discover how to overcome them.

Although stayrod fractures and wastage of stayrods and firebox plates occur only to a relatively small extent in Germany, these points have been studied in recent years by German as well as other metallurgists and railway engineers. A very comprehensive paper on this subject, presented to the annual meeting of the Institute of Metals at Düsseldorf, October, 1929, and since published,[1] provides an opportunity for further consideration of the whole question, and for a comparison of English and German experience.

The damage to be discussed includes: Stayrod fractures on the water side—mainly in the corners,—caused by the vibrational impulses imparted by the rail joints in addition to hot shearing; cracks in the flange of the tube plate on the fire side, from the same cause; surface damage of a general nature to the firebox and stayrods on the water side; and, lastly, the main object of the paper by Hudson and his colleagues—the surface wastage of the firebox on the fire side in the region of the brick arch, and the tightness of the stayrod threads.

Stayrod Fractures.

Stayrod fractures occur mainly in the corners of the firebox, the position of maximum stiffening, though they do not occur to any great extent in Germany when copper fireboxes are used. Individual steel fireboxes have, however, given rise to serious complaints owing to such fractures, and in some cases fractures have occurred to a very marked degree with copper fireboxes and stayrods. When the stayrods can be withdrawn without further damaging the fracture, the latter shows a smooth granular structure. This is surprising, as the tough copper stayrod might be expected to stretch rather than fracture; as this is not the case, the fracture must be regarded as due to fatigue, even though it does not show a smooth-worked zone as definitely as does steel. The chief cause of these fractures would seem to be the one-sided heating of the firebox, which on the fire side is exposed to temperatures of 1,200° to 1,300° C., whereas on the water side it is exposed only to about 200°. The copper thus tends to bow on the fire side. This is for the most part prevented by the stayrods, and the action is converted into a thrust, the firebox consequently trying to elongate towards the ends. Whereas bowing can readily be taken up by the stayrods as a tensile stress, the thrust due to the elongation of the firebox induces in the stayrods bending and torsional stresses which are more dangerous, as to these strong static stresses are added the fatigue stresses due to the rail joints. It is important, therefore, that the stayrods should possess a sufficiently high fatigue strength. For stayrod copper this is only 5 tons/sq. in., and an increase is desirable. It is obtainable to a limited extent by alloying with various constituents, as experience with manganese-copper has shown. Too great an increase makes the centre of the stayrod area so rigid that elastic arching is hindered, and the side and edge thrusts become too great.

Recrystallisation is also a possible cause of fracture, although it has not been found to any great extent in broken stayrods. When, however, stayrods with local recrystallisation are supplied and coarse-grained zones lie in that part of the stayrod subject to the main stress, the durability of the stayrod must suffer.

Firebox.

The so-called flange cracks in the tube plate serve as a further example. Apparently these cracks occur only under certain definite conditions of construction and service. The crack starts on the flange, where the shell thrust has also to be taken up, as an insignificant notch, which soon leads to fissures of quite considerable depth. The reason is obvious. Small folds, such as may easily form in the flange, still further reduce locally the already slight fatigue strength of the copper, and a crack which gradually increases in extent is started. The precautions to be taken are: Thorough cleaning of the inner surface, and prevention of excessive working of the flange walls.

The phenomenon forming the central point of the paper by Hudson and his colleagues is the so-called wastage—*i.e.*, the disappearance of material from the fire side of the wrapper. Wastage of this kind is also experienced in Germany, and is sometimes so heavy that the firebox has to be rebuilt, or at best the damaged areas replaced.

The attack is generally quite regular, the path of the products of combustion being obvious, there being no grooves or holes, while in some cases deep grooves form round the stayheads owing to wastage. The latter is due to the fact that, when the stayhead is riveted, the neighbouring surface of the firebox is heavily cold-stretched, and material in this condition is always more readily attacked by water, oxygen, and gases generally.

Cause of Wastage.

As to the cause of wastage, the outstanding question is: Is the phenomenon due mainly to the chemical action of the products of combustion, to corrosion under the influence of leakage, or to erosion by the stream of combustion products, and possibly coal thrown out of the grate? It is not easy to decide which of these three influences predominates. The English workers appear to consider chemical action the most important. They found that an arsenical copper containing about 0·5% As. formed, under the combined action of soot, smoke, and the products of combustion, a hard adherent scale which prevented further attack. In order that corrosion experiments could be carried out at the temperature of the firebox surface, the average plate temperature was determined by the English investigators by means of plugs of alloys of known (low) melting point, and found to be 200° to 300° C. This formed a starting point for the experiments.

Experiments on Chemical Action.

The experiments on the effect of gases on copper at different temperatures, and the formation of protective scales, were carried out at temperatures up to 600°, though the surface on which corrosion occurs must be hotter than this. However, the curves in Fig. 15 enable one to draw conclusions as to the probable results at higher temperatures.

* Translation from "Erfahrungen mit Stehbolzen- und Feuerbuchskupfer in England und Deutschland," *Zeitsch. f. Metallk.*, January, 1931, by I. Boodson, condensed.

[1] Hudson, Herbert, Ball, and Bucknall, "The Properties of Locomotive Firebox Plates and Stays," *J. Inst. Metals*, vol. 42 (1929), II., p. 221.

An improved apparatus, which allowed of the introduction of soot and smoke, is shown in Fig. 14. Fig. 15 shows the increase in weight after six hours with different gas mixtures. The oxidation curve for pure air, which is not given in the figure, lies somewhat below these curves.

The injurious effect of sulphur dioxide has also been experienced in Germany, but not that of chlorine. We can also confirm that leakage water increases the action of these agents. On the other hand, the theory of the protective action of the soot-copper oxide scale cannot quite be

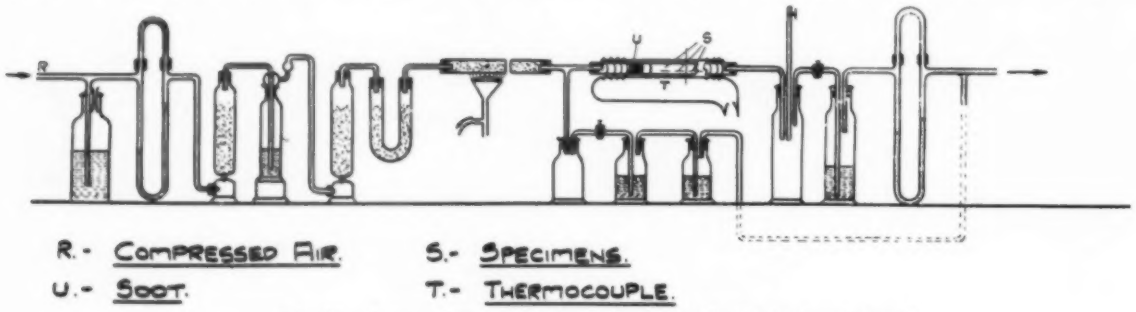


Fig. 14. Improved Corrosion Apparatus (for Effect of Soot and Smoke).

At 300° there were no noticeable differences, but at 400° the attack increased considerably. When oxygen-free mixtures were used, oxidation was very slight, but with an addition of 0·1% hydrochloric acid to the various gas mixtures a very marked attack was observed. Experiments were also carried out with hydrogen sulphide and sulphur dioxide, and it was found that the sulphide was mostly oxidised to the dioxide. The latter has a very marked effect, though it has only one-third the activity of chlorine. All these experiments failed, however, in one important respect—the scale formed was not as hard or as adherent as that formed on the fire side of the firebox under service conditions.

Further experiments showed that soot apparently played an important role, making possible the production of the kind of scale found in service, and considered by Hudson and others to have so good a protective action. These experiments were carried out in the improved apparatus previously mentioned. The mixture taken to imitate firebox gas contained 13 to 15% CO_2, 5 to 6% CO, 0·5 to 2·5% O_2, 1 to 2·5% H_2, 0·018% SO_2, and 0·03 to 0·05% HCl as Cl, which agrees fairly well with the average German chimney gas. Scale formation took place at temperatures up to 380°, but only when all the constituents, particularly soot and smoke, were present did the scale possess the desired character. Beyond 380° the scale lost its tenacity.

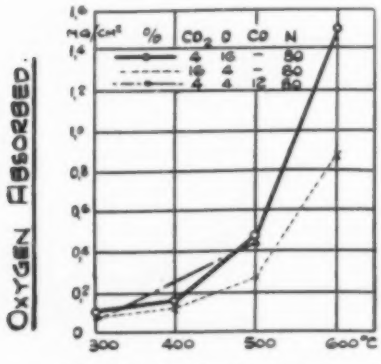
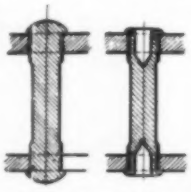


Fig. 15. Results of Corrosion Experiments.



Figs. 16 and 17. Types of Stayrod. Left—Riveted. Right—Drifted.

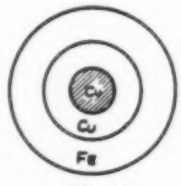


Fig. 18. Influence of Heat on Tightness of Fit.

In a further series of experiments it was found that both distilled and leakage water caused flaking of the scale by the chlorides and sulphates with which it is impregnated. The conclusion to be drawn from these investigations and observations is that the action of sulphur dioxide, chlorine, nd leakage water must be prevented as far as possible.

reconciled with German experience. It is known that locomotives fail from wastage despite this protective scale. Further, individual leakage positions, at which the scale is strongly green and white coloured, are found in areas of regular wastage, though no greater local wastage is noticeable.

Leakage Round Stayrods.

Whatever the cause, leakage round stayrods is so undesirable that it must be combated by every means at command. In Germany these troubles have been overcome, independently of the material, by suitable methods of tightening the stayrods in the threads, either by riveting or drifting. The two types are shown in Figs. 16 and 17.

The authors of the English paper show the use of alloyed stayrods to be of special importance by a relatively simple experiment. A suitable plug, representing the stayrod was accurately fitted in a copper ring, which was in turn fitted in a steel ring (Fig. 18). After heating to a minimum temperature of 250° and cooling, the plug fell out. When copper containing 0·5% tin was similarly tested, the plug became loose, but not to the same extent. The effect of higher temperatures need not be considered in this connection, as the majority of the threads lie near the firebox plate, on which the water side has a cooling effect, and are consequently scarcely above 250°.

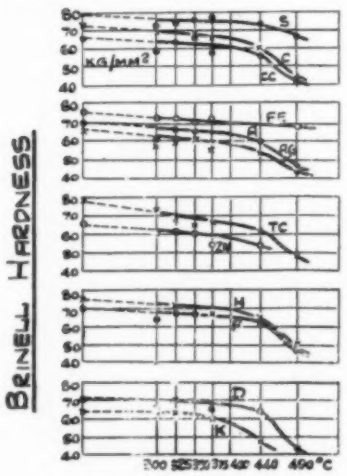


Fig. 19. Hardness at Elevated Temperatures of Copper Alloys Reduced 5 to 10% by Cold Work.

Brinell Hardness.

For the hardness tests cylinders were compressed cold by 5 to 10%, the Brinell hardness determined (40-kilo. load, 2 mm. ball, 30 secs.), the cylinders heated for two hours at 300°, 400°, and 500°, and the decrease in hardness determined. The alloys tested contained 0·5% Mn, 0·75% Si, 0·05% Ag, 1% Sn, and 0·5% Fe respectively.[2]

The results of these tests are shown in Fig. 19 as in the original paper, and in a rearranged form for greater clarity in Fig. 20. Above 440° there is a marked fall from 65/80 to 45/50, or about 15 kilog./mm². The more satisfactory behaviour of the alloys to the right up to 440° is apparent.

[2] In the figs. these are designated 9 D, 10 S, 11 A G, 13 E, and 14 F E respectively.

11 A G appears to be somewhat away from the others, but this is due solely to its lower initial hardness. A noticeable softening occurs at 490°, but this temperature is of little importance where stayrods are concerned.

The softening effect of temperature is more marked after 30 to 50% reductions, where the initial hardness varies

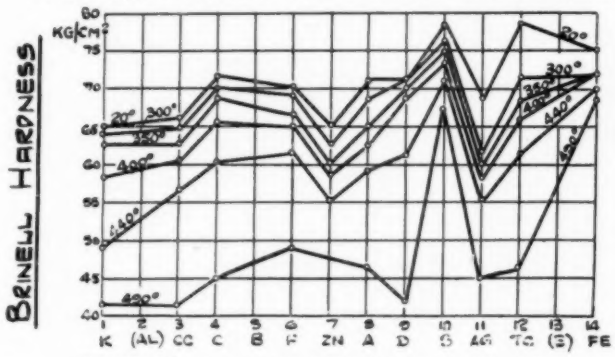


Fig. 20. Rearrangement of Results given in Fig. 19.

from 90 to 120. These results are shown in Fig. 21 (as in original paper) and Fig. 22 (rearranged). In this series the alloys to the left were markedly softened even at 300°, whilst at 350° the majority, except only those to the extreme right, were affected.

TABLE I.

TENSILE PROPERTIES OF COPPER ALLOYS AT ROOM TEMPERATURE.
(Annealed 7 hours at 300° C., cooled and reheated for 100 hours at 300° C.)

Mark.	Alloying Addition, %.	Percentage Reduction by Cold-work.	Brinell Hardness Number (2·10·30).	Limit of Proportionality, Tons Sq. In.	Ultimate Tensile Strength, Tons Sq. In.	Elongation, % on 2 in.
X 13	As 0·5	10·0	63	3·6	15·6	49
X 53	As 0·5	50·0	54	1·2	15·2	58
A G 23	Ag 0·05	5·7	66	8·0	15·9	52
A G 53	Ag 0·05	28·6	72	5·2	18·0	37
S 23	Si 0·74	5·7	69	7·6	18·9	48
S 53	Si 0·74	28·6	82	8·0	21·7	35
F E 23	Fe 0·52	5·7	68	8·0	17·2	48
F E 53	Fe 0·52	28·6	79	10·0	19·9	34

As alloyed stayrods have been used in Germany for some years, experiments, less comprehensive perhaps, were carried out here, and comparative values obtained for normal copper with less than 0·07% As, arsenical copper with 0·4% As, and copper with 0·44% Sn. Cylinders

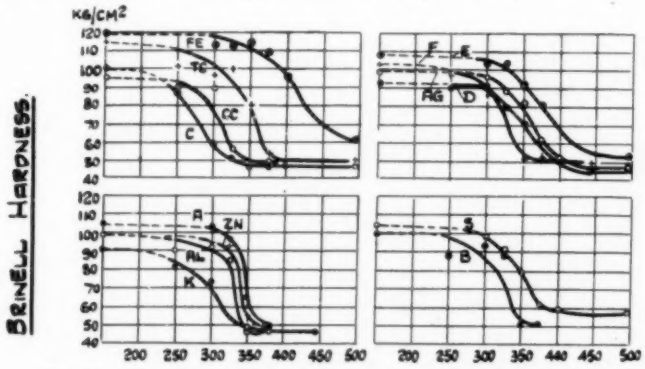


Fig. 21. Hardness at Elevated Temperatures of Hard Drawn Copper Alloys.

20 mm. diameter were reduced 10 and 20% by cold stamping, and after 24 hours' heating at 200°, 250°, 300°, and 400°, were tested on the Brinell machine at the same temperatures. The load was 500 kilogs., the ball diameter 10 mm., and the loading period 3 mins. The apparatus, consisting of a Brinell machine with an electrically heated oilbath, is shown in Fig. 23. The results for the three materials are shown in Fig. 24.

It will be seen that in the first place the effect of heavy reductions is nullified. The results also confirm those of the English workers, in that arsenical copper, unlike tin-containing copper, possesses no exceptional hardness at high temperatures.

Opportunity was also taken to determine the reduction in notch toughness caused by arsenic (about 0·4%), and as a mean of four tests it was found that the notch toughness

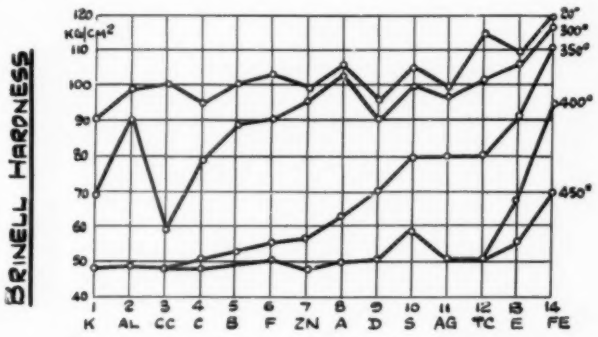


Fig. 22. Rearrangement of Results given in Fig. 21.

(with a 10-metre-kilog. blow) fell from approximately 10 mkg.[3] for low-arsenic and for tin-containing copper to 8 mkg.[4] for arsenical copper.

TABLE II.

LIMIT OF PROPORTIONALITY OF COPPER ALLOYS AT ELEVATED TEMPERATURES.
(The limit of proportionality at room temperature is given in the last column; the test-pieces were all annealed for 2 hours at 300° C. prior to test).

Mark.	Alloying Addition, %.	Percentage Reduction by Cold-work.	Temperature of Test, ° C.	Corresponding Limit of Proportionality, Tons /Sq. In.	Limit of Proportionality at Room Temp. Tons /Sq. In.
AG 25	Ag 0·05	5·7	292	4·0	5·2
A G 28	Ag 0·05	5·7	365	2·8	5·2
A G 15	Ag 0·05	10·0	296	3·0	4·4
C C 15	As 0·43	10·0	296	1·2	3·2
Z N 18	Zn 0·18	10·0	297	3·6	5·2
S 26	Si 0·74	5·7	300	4·4	6·4
F E 15	Fe 0·52	10·0	312	3·2	6·0
F E 17	Fe 0·52	10·0	292	4·4	6·0
H 18	Ag 0·093	10·0	305	3·2	3·6
H 28	Ag 0·093	20·0	297	2·4	5·2
D 18	Mn 0·46	10·0	308	3·2	3·6
T C 18	(Sn 0·82 / Cd 0·30)	10·0	298	4·8	5·2

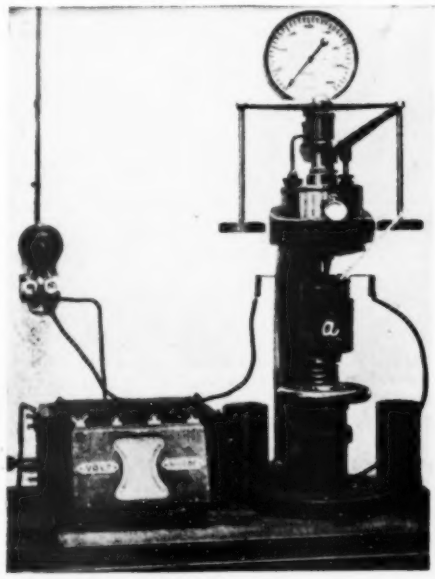


Fig. 23. Brinell Machine for Tests at Elevated Temperatures.

Hot stamping tests were also carried out. The cylinder, were compressed at 850° to one-third their original heights no disadvantage due to arsenic being noticeable.

3 and 4, 72·3 and 57·8 ft.-lb. respectively.

Tensile Tests.

Reverting to the English experiments, the tensile tests may be considered. The first series was carried out at room temperature after prolonged heating at 300°. Samples of the alloys used for the Brinell tests were annealed, cold-

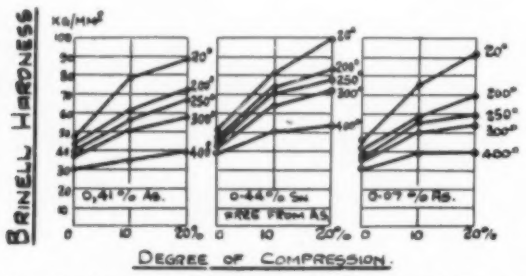


Fig. 24.—Hardness at Elevated Temperatures of Stayrod Copper after Compression (Individual Experiments).

worked, heated as stated, then tested. From the results given in Table I. it will be seen that silver gives a higher elastic limit than arsenic—5 to 8 tons/sq. in., against 1·2 to 3·6.

The second series was carried out at about 300°. These test-pieces had also been previously cold worked after annealing. The individual values for the elastic limit (proportionality limit) in these tests came closer together, and were mostly 3 to 4 tons/sq. in. (Table II.). The silver-copper alloys again gave satisfactory values.

The author has carried out tensile tests at high temperatures, without previous cold working, on three qualities of copper—copper containing 0·38% As, copper containing 0·43% Sn, and a low-arsenic copper (0·15%)—the samples being used in the form of hollow stayrod copper. The results at temperatures of 100, 200, 300, and 400° are shown in Fig. 25 (mean of two tests); the superiority of the tin-copper alloy is obvious.

Fatigue bend tests were also carried out on these three qualities of copper, using the Amsler machine. Special test-pieces were forged and then drawn to the dimensions shown in Fig. 26.[5] Although the cross-sectional area could

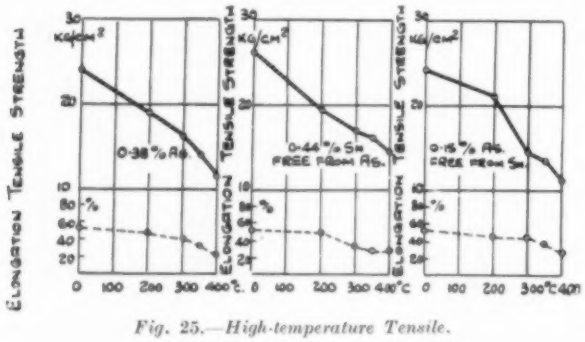


Fig. 25.—High-temperature Tensile.

not be accurately determined owing to the internal cavity, the results obtained for the fatigue strength, which have since been checked on solid copper, were: Copper with 0·38% As, 8 kilog./mm.²; copper with 0·15% As, 7·5% kilog./mm.²; and copper with 0·43% Sn, 9·5% kilog./mm.².[6]

Summary.

Briefly summarising the results, three conclusions as to the corroding influences are reached:—

1. The influence of temperature, particularly above 400°, is greater than that of variations in the gas mixture—CO_2, CO, and O_2.

2. The influence of hydrochloric acid and of sulphur dioxide is also greater than that of variations in the gas mixture. At 400° the effect of 0·1% hydrochloric acid is about sixty times that of the gases, whilst that of 0·1% sulphur dioxide is about one-third that of the acid, but about twenty times that of the gases.

3. Leakage water, whether or not free from corrosive salts, causes catalytic action by the chlorides and sulphur compounds with which the oxide scale is impregnated.

The first of these appears to be the most important. Where the flames exert a strong local action, mainly around the brick arch, excessive wastage and looseness are encountered, despite the protective soot-oxide scale; the surface temperatures here are at least 600°.

The possibility of obtaining greater strength at elevated temperatures by alloying the copper was investigated by means of hardness and tensile tests, and it seems likely that good results would ensue from small additions of silver, tin, silicon, and iron.

Further long-period tests are being carried out by Hudson and his colleagues, but in the author's opinion compression tests at elevated temperatures would have been more advisable, whilst to carry out both would be best of all. Load reversal experiments at high temperatures should also be undertaken.

Care must be taken in choosing an alloy, as too high a tensile strength when hot may increase the risk of stayrod

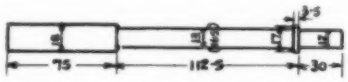


Fig. 26.—Test Piece for Fatigue Bend Tests on Copper. (Amsler Machine).

fracture. The English workers have been very cautious in their choice of alloys, and it may be assumed that their experience with copper containing small amounts of silver has been quite satisfactory.

The German State Railway Company is also carrying out practical trials with a heat-resisting tin-copper alloy, and it would perhaps be better to await the results of these trials before entering on a further theoretical discussion of present knowledge on this point. It is, however, gratifying to have had the opportunity of giving an account of what has been, and what still needs to be, done towards solving this very important question of material.

Aluminium for Cleaning Precious Metals.

A PROCESS for cleaning silver by the use of aluminium has been devised and is patented. The process is based upon the fact that when aluminium is brought into contact with silver (or other precious metal) in an alkaline solution, an electro-chemical action is set up which dissolves all tarnish and stains. The procedure in cleaning silver, electro-plate, or jewellery is simply to place the articles in a hot weak solution of soda in a non-metallic basin with a Polivit plate, which consists of a small rectangular perforated plate of aluminium. After about five minutes immersion the articles are clean and ready for removal, rinsing, and drying.

In addition to its obvious ease, the process is claimed to have other advantages; it saves time, thoroughly cleans inaccessible parts, does not scratch or wear the articles cleaned, and is economical, as the aluminium plate will last a long time. The aluminium is an alloy which has been found to be best suited for the purpose. This process, which has been found especially useful by big clubs, hotels, railway and steamship companies, has been commercialised by the Polivit Manufacturing Co., Ltd., 21, Old Queen Street, Westminster, S.W.

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5 Half-length test pieces only were used for these tests.
6 5·1, 4·76, and 6·0 tons/sq. in. respectively.

Nickel and Nickel Alloys in Marine Engineering

The present demand for materials which will retain strength and resist corrosion at temperatures above 400°C, is presenting Marine Engineering problems, some of which are being solved with the aid of Nickel and Nickel Alloys.

OF all the metals and alloys used in ship construction, mild steel and cast iron represent by far the greatest proportion. The ratio of these to other metals is, however, decreasing slightly, but nevertheless progressively. These metals have themselves been improved in quality, but for many applications have been replaced by either special alloy steels or non-ferrous metals. Corrosion still remains a problem, although for many uses suitable corrosion-resisting alloys are now available. The introduction of higher steam pressures and temperatures has created a demand for materials resistant to fracture or deterioration under these conditions. Possibly the most pressing demand at present is for materials which will retain strength and resist corrosion at temperatures above 400° C.

In the solution of some of these marine engineering problems nickel and nickel alloys have been employed, or specially developed, and in a paper given before the Institute of Marine Engineers on December 8, Mr. J. McNeill indicated the extent to which these materials are now used.

Although not widely used in marine engineering, pure nickel has quite definite applications in this field. The author referred particularly to the use of heavy nickel deposits for truly engineering purposes, and stated that by strict scientific control of the nickel deposition process it is possible to form thick nickel deposits which show remarkable adhesion to the underlying metal. A typical instance of its use in repair work was described in which shafts for reduction gearing which had worked loose were built up by an electrolytic deposit of nickel with complete success. Repairs of a similar type have been carried out to damaged turbine wheels, worn piston rods, valve spindles, crossheads and pins, Diesel engine gudgeon pins, etc.

This application of nickel, however, is not confined to repair work, but is used for initial production purposes. For example, corrosion of expansion sleeves often necessitates frequent repairs. In many cases these sleeves are now protected initially by a nickel deposit. Cast-iron propellers, too, are sometimes initially protected in this way. Nickel also has many applications in electrical auxiliary marine equipment, and it possesses several outstanding features which render it suitable for cooking utensils such as are required for marine service.

Copper-nickel Alloys.

It is in non-ferrous alloys, however, that nickel has a wide range of application in the marine field. The chief source of corrosion in marine work is attack by sea-water, and resistance to this is one of the outstanding features of the nickel-copper group of alloys. The degree of resistance increases with nickel content. Probably the most resistant alloys to sea-water corrosion, and indeed to corrosion in general, are those containing between 60 and 70% nickel.

One of the most important applications of the lower nickel content alloys is for condenser tubes. For this purpose alloys containing 20 and to a greater extent 30% nickel are being largely employed. Condenser tube corrosion has been a persistently recurring evil in marine engineering, and until the development of cupro-nickel alloys in tube form this question still remained a problem, and, in fact, had considerable bearing on the delay in the adoption of water-tube boilers for marine propulsion. Now 70–30 cupro-nickel tubes have become standard for installations where water-tube boilers are employed. This minimum nickel content has been arrived at by long and persevering trials. Results, however, have fully compensated for the many set-backs in the course of development. It is of interest to note that so far no reports of failures of this quality of tubing in marine installations have been received.

A rather similar application is the use of these tubes in oil coolers. The exceptionally satisfactory results obtained in condensers have perhaps tended to obscure the important service they have rendered in intercoolers, oil coolers, fresh-water coolers, piston cooling tubes, etc., and Mr. McNeill gave some interesting examples of service in this connection.

Monel Metal.

The remarkable resistance of the 70–30% nickel-copper alloy to sea-water corrosion and to retention of strength at steam temperatures, was particularly referred to. Monel metal is the only alloy approximating to this composition which is at present available, and the author gave a few references to its applications. Arising out of its combination of sea-water corrosion resistance and high strength, it is employed extensively for propeller shafts of speed-boats.

It is admirably suited for turbine blading, as it is practically immune from the cutting action of superheated steam, retains its strength at steam temperatures, and can be drawn to very accurate sections with sharp edges and smooth surfaces. The successful application of Monel metal for this purpose is indicated by the fact that the majority of the turbine-driven vessels built in this country during the past six years, whether warships or merchant vessels, have used Monel metal reaction blading for the high-pressure turbines. In several cases Monel metal is being fitted right down to the low-pressure end. Shrouding strip and binding wires are generally made of the same material, but the packing pieces are usually of soft iron. Many foreign navies and shipbuilders are following the same practice.

Another somewhat important application of Monel metal in connection with turbines, which is of more recent development, is the casting-in of Monel metal nozzle plates into cast iron. A number of these have now been produced, and it is found that Monel metal is in no way impaired by the casting-in operation.

Its use for valve parts in steam-lines is well known, but it is of interest to mention that the *Bremen* has forty large superheated steam-valve bodies of Monel metal, while a large consignment of Monel metal-cast valves parts was supplied for the P. and O. turbo-electric steamships *Strathnaver* and *Strathaird*. The latter vessels work with steam at a pressure of 425 lb. per sq. in., and a final steam temperature of 725° F.

Other applications of this alloy in connection with marine work include pump impellers, valve seats, spindles, and packing rings in steampipe lines; valve seats in fuel oil pipeline valves, and for mosquito netting for covering portholes in vessels trading in tropical waters. In the construction of small motor boats it is used for propellers, petrol tanks, nuts and bolts, also fittings such as staytangs for the masts of sailing yachts. Considerable quantities are also now used for pantry, bar, cabin, and deck fittings, etc.

Nickel-copper-tin Alloys.

While Monel metal is used to a considerable extent for steam valve parts, there are many types of valves in which a material is required for parts used in rubbing contact and for which non-seizing properties are required. For such purposes various additions are made to nickel-copper alloys

to produce a material of suitable structure. First, there are alloys of nickel, copper, and tin, or chromium and iron, which are extensively used under various trade names. By such additions, alloys having structures more of the nature of bearing metals are obtainable. Such alloys have a Brinell hardness value in the region of 250 to 300. Their tensile strength may be as high as 36 tons per sq. in. at ordinary temperatures, while they retain some 20 tons per sq. in. at 500° C.

Non-ferrous Materials with Lower Nickel Content.

The use of the lower nickel content non-ferrous materials is rather limited, but nevertheless quite important, and the author gave a few typical applications, such as, for instance, the extensive use of nickel-bronze for ships' propellers. A typical example of nickel-bronze for this purpose being "Turbadium" bronze, which has the following approximate composition :—

Copper, 49-51 per cent.
Zinc, 45-49 per cent.
Nickel, 2 per cent.

Balance tin, iron, manganese, and aluminium. Reference was also made to the use of nickel-silver alloys, containing Cu, Ni, and zinc, for marine purposes, which is practically confined to sanitary fittings and ornamental work. Their use for sanitary work is by no means new, but the alloys used in past years contained fairly low nickel contents, approximately 12–14%. Within the last two years, alloys containing 20–22% nickel have been developed, and are replacing the lower nickel-content materials in this field.

Considerable advances have been made in the development of alloys combining both lightness and strength, and these are now being increasingly employed for marine engineering applications. "Y" alloy and the group of R. R. alloys are typical of these, each of which contain from 1 to 2% nickel in their composition. Remarkably good properties are obtainable from these alloys by heat-treatment, and they show comparatively good retention of strength at temperatures up to some 300° C. In the marine field they are being used chiefly for pistons of Diesel engines, while for the smaller engines they are also being used for connecting rods, crankcases and various miscellaneous castings. The production of forged connecting rods in these alloys for large Diesel engines is at present under investigation, and it seems quite probable that these will be quickly developed.

Heat-resisting Alloys.

There is another group of alloys which are applicable for use at considerably higher temperatures—namely, the nickel-chromium and nickel-chromium-iron alloys. The most widely used alloy of this series is that containing 80 nickel, 20 chromium. This is one of the strongest materials at present available for high-temperature work. In marine engineering, apart from electrical-heating appliances, the use of heat-resisting alloys is at present limited to some parts of boilers and Diesel engine exhaust valves. For instance, the baffle plates of furnace doors, the furnace refractory arch supports, and oil-fuel burners, and the superheater tube supports are all subject to severe conditions. For such applications nickel-chromium-iron alloys, such as "Cronite," which contains approximately 65% nickel, 15% chromium are being employed with satisfaction. These ternary alloys, with small special element additions, are more resistant to attack by sulphur-containing atmospheres than are the straight nickel-chromium alloys.

Nickel Cast Iron.

Cast iron represents a considerable percentage of the total weight of metals and alloys used in ship construction, and during recent years endeavours have been made to improve the quality of cast iron both by more stringent control of composition and by special alloy additions. Of the latter, nickel has proved particularly useful. Its effects on various cast-iron compositions have been investigated in the laboratory and proved in service.

The addition of nickel to cast iron has facilitated the production of castings of close grain without the risk of chill and subsequent trouble in machining. Such nickel cast irons are certainly advantageous for the manufacture of parts where pressure tightness is essential, as, for instance, in the case of ammonia compressors. One of the first results of the densening effect of nickel additions is that castings can be obtained which show definite improvements in wearing properties. A typical example where wear is of importance in marine engineering is the liners of large Diesel engines, and as a result of comparative tests mentioned by the author, there is apparently no doubt as to the suitability of nickel cast iron for this and similar uses.

Nickel Alloy Steels.

The very wide range of materials and uses covered by nickel alloy steels could not adequately be dealt with in this paper, and the author confined himself to a brief description of their general properties, and gave some typical applications. The important advantages obtainable in nickel steels over the ordinary carbon steels include more rapid heat-treatment, improved mechanical properties, and the reproduction of these properties with regularity.

One of the most generally used of the nickel steels is that containing 3·5% nickel. The chief feature of this steel is its exceedingly high toughness and ductility, which are obtainable with good maximum stress and yield ratios. Its uses include Diesel engine connecting rods, crankshafts, reduction gears, turbine rotor discs, and shafts. A considerable quantity of alloy steels of the higher alloy contents are now used as turbine blading materials, and also for nozzle vanes. These steels have a coefficient of expansion which permits them to be "cast-in" to cast iron boxes. The nickel-chromium austenitic non-corroding steels, being non-magnetic, are particularly suitable for parts for use in the vicinity of the magnetic compass, not only for bridge and deckhouse parts, but for shafts and other components of the steering mechanism. They are also employed for the gudgeon washers of steering rudders, for pump shafts, dock sluice gates, and actuating mechanism.

British Standards Specification.

Lathe Centres.—The existing divergencies and variations in engineering practice with regard to the most suitable angle for lathe centres have recently been investigated by a Committee of the British Standards Institution, and their recommendations have been embodied in British Standard Specification No. 426-1931, "Lathe Centres," which has just been issued. Recommended sizes of work centres to be used for various weights of work and speeds of cutting are given in three charts, and this information will be most helpful to all engineering workshops. A critical investigation on theoretical grounds of the comparative merits of the more commonly used 60° and 90° angles is also given in an appendix.

Diamond Pyramid Hardness Numbers.—The increasing use of case-hardened and high-tensile steels has led to a more extensive adoption of the diamond pyramid indentation test in preference to the Brinell test, with which inaccuracy occurs with high loads, owing to ball distortion. This has given rise to the need for recognised tables of hardness numbers, corresponding to the British Standard Brinell numbers, and this need has now been met by the British Standards Institution in B.S. Report No. 427-1931, "Diamond Pyramid Hardness Numbers," just issued.

Details as to the method of carrying out the test are laid down, and tables of hardness numbers are given for loads of 5, 10, 20, 30, 50, 100 and 120 kgs. A pyramid having an angle of 136° has been specified as the standard, but an indication is also given of the allowance to be made for machines using an angle of 140°.

Copies of these specifications can be obtained from the British Standards Institution Publications Department, 28, Victoria Street, S.W. 1. Price 2s. 2d. each post free.

The New Alloys and——— Machine-tool Design

By Francis W. Shaw, M.I.P.E.

Part VI.—Measuring Devices.

With every decrease in the cut-time the measuring time looms ever larger and larger, often exceeding the cut-time. Means for accelerating measuring are discussed. It is shown that direct measurement is rapidly yielding to measurement by comparison with master-pieces or accurate standards.

THE necessity for lessening the ever-growing disparity between the cut-time and the non-cut-time, due to improvements in cutting materials, to which previous instalments have drawn attention, has given impetus to speedier means for checking the dimensions of the work-piece during the production stages.

If machines and tools were wearless, and the material operated upon faultless, gauging apparatus would be needed only as a means for controlling the accuracy of the first piece produced in a run of work. And then the gauging would virtually be for the purpose of correctly correlating the dimension-controlling elements of the machine and the tools with the divers elements of the work-piece.

Instead of actually producing a piece as a means to this accurate positioning, we might employ an already finished piece or "master," or even a number of "masters," each presenting a portion of the form or outline of the finished work-piece. The masters might sometimes take the form of standard fixed gauges or test bars.

Common and good-enough procedure where the error tolerances are large enough to allow for the yield of machine parts and tools or of the material of the work-piece, arising from the cutting forces, to which the master or masters are not subjected. When the error due to this yield exceeds that permissible, the master still affords a ready means for approximate initial adjustments, the amount of the final adjustments being then determined from the dimensional differences between a first-produced piece and the master.

The master method has long been recognised as a way to reducing the adjusting and re-setting factors—factors 3 and 4 of those enumerated in Part III. It is worthy of wider adoption.

Measurement by Comparison.

But since machines and tools do wear, and no material is perfect, the initial accurate adjustments, however effected, cannot be maintained, and, therefore, some means are essential for revealing disturbances in the adjustments and tool wear—a revelation that will obviously follow dimensional comparison of the work-piece with some master.

Whilst caliper and plug-and-ring and other fixed gauges, both "size" and "limit," have increased in use, the micrometer and the vernier-caliper hold sway even to-day: indeed, are convenient adjuncts of the fixed gauges, for they indicate to the operator the amount of material to be removed, enabling him to adjust the tools either by estimation or by help of the micrometer collars and dials now generously fitted to feed-screws and feed-shafts. For the final check, time is saved by utilising a master for setting micrometers, or even the ordinary calipers, still serviceable to the skilled operator.

But even the master does not obviate all the time wastage, and to set adjustable instruments occupies a considerable portion of the total time. Besides, the micrometer and the vernier are easily to be misread. Though time and scrap are minimised by micrometers of the direct-reading type, such as the Brown and Sharpe, and the Starrett, even these require time to adjust from size to size. And not one prevents the readings differing according to the "feel" of the user.

For the exacting requirements of interchangeable production, measurement should be shorn from dependence upon feel—so variable. That full realisation has come of this witnesses the recent study of what, from a manufacturing standpoint, can be regarded as a new system of measurement—*indirect* measurement by comparison with accurate standards—by comparators, so-called.

It may not be generally realised that the principle of all mechanical comparators—we say "mechanical" to differentiate them from instruments depending on lenses, and mirrors, and light-wave interferences—is that of the historic Whitworth measuring machine, in which the dimension to be measured was compared with the length of the nearest standard measuring rod—exceedingly accurate. Exactly as in this machine dimensional differences between the work-pieces and the measuring-rods only were revealed, so in the modern comparators the reading is not of the complete dimension, but of the amount whereby it differs from that of some accurate gauge, test-piece, or master work-piece, by which the comparator has already been set or calibrated.

Since, in all these instruments, the dimensional difference is vastly multiplied at the indicating device, or "clock," reading is immediate, the time consumed being but that occupied in applying the instrument to the work-piece. And even this little loss is obviated where, as in some processes, the instrument may remain in contact with the part being gauged.

The pressure required to operate the clock being exceedingly small, its influence upon the reading is negligible.

Until quite recently the construction of comparators was such as to limit their application to checking the work upon completion—they were essentially bench machines,—the operator being still wholly dependent upon his calipers, his micrometer, his vernier caliper, and his ordinary gauges for detecting errors arising as work proceeded.

Many of the newer comparators are, however, adapted either for hand use or to be supported on the production machines for immediate application to the work-piece. Further, not rarely they are, in fact, an integral part of the machine tool, having been constructed to meet the preconceived methods that instigated the design.

Desiderata of Comparators.

In instruments for gauging work during its progress the desiderata are:—(1) They should be light and easy to manipulate: (2) they should not only indicate (by comparison) dimensional differences, but any given tolerance immediately and free from ambiguity: (3) they should indicate the dimensional excess at any instant: (4) they should be rapidly adjustable from size to size: (5) they should not jam, as does the micrometer, if slightly tilted, and it should be possible for the operator to detect and immediately eliminate any tilt: (6) the measuring points should not pass beyond the points to be gauged: (7) they should be sensitive, applying little pressure to the work-piece: (8) the heat induced by contact with the work-piece, or the hand, should not appreciably affect the reading: (9) the movable contact point or points should retreat easily, so as to obviate undue friction as they pass on to the work-piece: (10) the contact points should be smooth

and hard, so as not to scratch the surfaces, and for durability's sake; (11) they should admit of a fair amount of misuse, and parts liable to suffer by use or misuse should be readily and cheaply reparable or renewable.

The ideal instrument would be one as simple as, and of range equal to that of, the micrometer. In not one of the

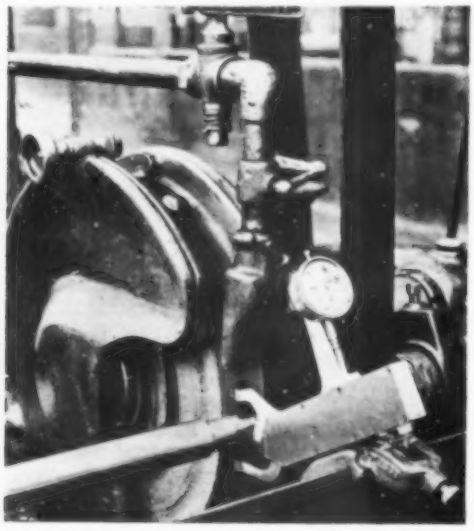


Fig. 39.—Churchill sizing gauge, adapted to slide on the grinding machine table or head guides, is quickly removable to allow the work to be inserted or removed. The measuring points remain in contact with the work during the operation, the clock indicator continuously registering the diameter.

comparators with which we are acquainted are the desiderata fully met; yet met they must be if the instruments are to rank for general convenience with those they displace. Imagine, for instance, the checking of a multi-diametered piece. With one or two micrometers and a single pair of calipers, or a vernier caliper, it is possible to gauge every diameter, whereas as many comparators would be needed as there are diameters. It is conceivable that a comparator might be designed with a range comparable at least with that of the micrometer, its measuring points rapidly and accurately adjustable in steps, say, of $\frac{1}{16}$ in., this small amount being left for the "clock" to register. In current instruments, as we know them, the large adjustments are made by interchanging the gauging points or blocks, or by unlocking, adjusting, and re-locking the screws forming or carrying the gauging points. And since, generally, each adjustment necessitates re-calibration to standard gauges or masters, so much time is expended at every re-setting that the only practicable course is to employ a separate instrument for each different nominal diameter.

Though this is a difficulty that almost precludes the use of comparators for lathe work, and any other work where many dimensions must be attained at a single setting, and for small-quantity production, it is not so pronounced where the dimensions are few and the quantities large.

The operation of grinding, perhaps, presents the widest field for the comparator, for the majority of the work, given a reasonable quantity, permits of the grinding of each element of the piece at a single setting. And, fortunately, in modern works practice, the final operation is grinding: the general experience having been that in all except the roughest classes of work, even where extreme accuracy is not essential, but good finish is desirable, less time is consumed in the process of grinding than by the older methods. Indeed, it has frequently proved profitable to finish surfaces outright from the "black," altogether eliminating the metal-cutting machines.

Comparators Adapted for Grinding Machine Use.

In repetition grinding a large proportion of the total time is consumed in gauging by the older types of instruments. Not only do these instruments necessitate stopping the machine for every gauging, but gaugings are apt to be numerous: the more numerous, the more fearful the operator is of getting the work under size.

With the comparators about to be described, since they register but differences of dimensions from the nominal, applied to grinding machines after the fashion accompanying illustrations reveal, gauging can be said to be automatic on repetition work, for, after the "clock" has been set to zero during the grinding of the first piece (gauged carefully by ordinary means), or by a cylindrical test-bar or master, the comparator can be left in position, in contact with subsequent work-pieces, as grinding proceeds. Thus, at every instant, the amount of metal remaining to be removed is indicated, enabling the operator to adjust the abrasive wheel, or control it, if the in-feed is automatic, as circumstances dictate. The only concern of the operator, then, is to watch the "clock" and "see" that the feed does not proceed after the clock indicates zero or has crept within the tolerance points.

They who have witnessed the watchful attention of the

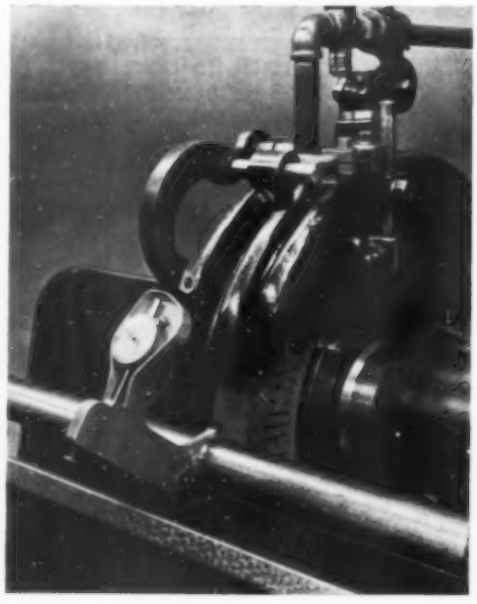


Fig. 40.—Churchill indicating sizing gauge in continuous contact with the work-piece, indicating that the required dimension has been attained, warning the operator that grinding must cease.

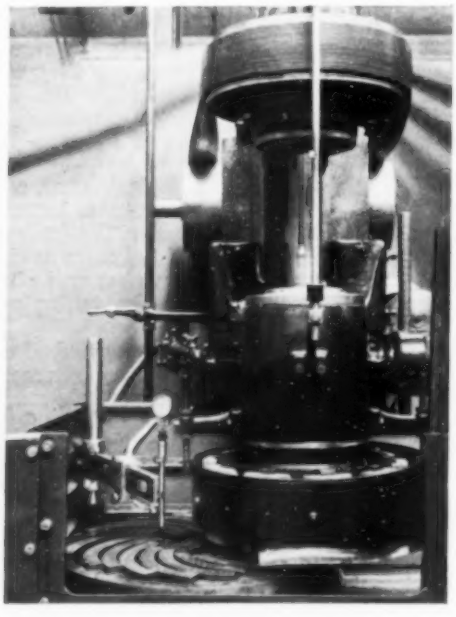


Fig. 41.—Churchill sizing gauge applied to a surface-grinding machine.

grinder as the desired size is approaching will not be surprised to learn that these instruments seldom save less than a third of the total time, and that the saving on the smaller work may be nearly all the time. And how much our fatigue factor (10) can be affected—for mental fatigue is ordinarily as destructive of a man's staying powers as physical—is hardly to be determined. It is nearly safe to say that all the saving will be effective, notwithstanding the increase in the number of pieces handled.

Pratt Grinding Gauge.

Of the comparators utilising a dial indicator of more or less standard construction, in which the dial can be rotated to bring the zero mark into line with the pointer, the Pratt grinding gauge (sole licensees for Great Britain: Industry and Commerce Alliance, Ltd.), while operating on the general lines of all similar comparators, possesses several features of merit.

In this type the indicator proper is suspended from a series of levers, adjustable to permit of the measuring jaws being located in convenient relationship with the work-piece, and held out of contact therewith at leading periods.

The complete outfit comprises the means of attachment to the machine, and a range of calipers or caliper frames to cover all diameters from $\frac{1}{4}$ in. to $4\frac{1}{2}$ in. Special calipers are furnished for smaller work, for gauging tapers, and to operate in narrow grooves or recesses. In instruments adapted to bridge across transverse and longitudinal grooves the three contact screws are each fitted with two separated contact points. The contact points, being polished diamonds, are practically wearless, and do not scratch the work surface; neither do they need adjusting.

Churchill Indicating Sizing Gauges.

In the comparators fitted, if desired, to the cylindrical and other grinding machines of the Churchill Machine Tool Co., Ltd., the comparator proper is fulcrumed by a series of levers to the abrasive wheel-guard, or to a bracket arranged to slide on the work-head guides, as in Figs. 39 and 40.

The contact blocks are of abrasion-resisting steel, the gauging surfaces of the upper and rear blocks being located at right angles to one another, the lower block being pivotally connected to the indicator through the multiplying lever device. Each set of three blocks covers a range of $\frac{1}{8}$ in. in the work diameter, the 14 sets provided with the smallest of three sizes of instruments thus covering all diameters from $\frac{5}{16}$ in. to 2 in. The other sizes cover diameters from $\frac{7}{8}$ in. to $2\frac{1}{2}$ in., and from $1\frac{7}{8}$ in. to $4\frac{1}{8}$ in.

Fig. 41 illustrates the same principle of gauging applied to flat objects being ground in a Churchill surface grinder. The "clock" is set to zero, or as desired in relationship to the nominal thickness dimension, according to the position of the tolerance, either in grinding the first pieces of a batch or to an accurate thickness gauge.

Where the work surface is interrupted, as is that in the illustration, a dashpot is fitted to the multiplying lever (additional to that in the indicator itself) which connects the contact bar to the indicator mechanism: the object of the dashpot being to prevent the jar that would result from the gauging point striking the corners of the work-pieces, rendering reading difficult.

So sensitive are instruments of the Pratt and Churchill type that not only do they detect normal diameter variations, but those due to rough grinding and to chatter.

Difficulty of Detecting Cylindricity Errors.

How many engineers, either theoretical or practical, realise that the micrometer, however accurate, however sensitive, and however skilfully used, is not an infallible test for cylindricity, or lack of it? That there is an infinity of shapes other than circular that fit equally precisely between two parallel lines? That any of these shapes, in any position, touch the four sides of a square or of any rhombus? That any three fixed points can trace out any number of different figures? That any four, five, or any greater number of points distributed anyhow in a circle can travel in the contour of an infinite number of different figures, not one of the points ever straying therefrom?

This is hardly the place in which the discuss the mathematical aspect of the problem, and, therefore, we content ourselves with illustrating, in Fig. 42, a circle, A; a trilobe, B; a quirquelobe, C; of whose form-difference the micrometer is oblivious, for each fits equally precisely between two parallel lines, which may be said to represent the planes of the measuring faces of a micrometer. At D are shown a bilobe and a circle between which a 3-point gauge is unable to differentiate, and at E another trilobe and a circle between which a 4-point gauge cannot distinguish.

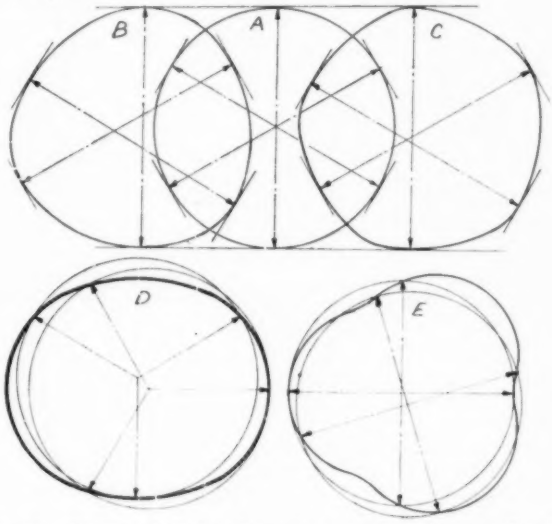


Fig. 42.—Figures which the micrometer, or any 2-point gauge, 3-point and 4-point gauge, cannot distinguish from circles.

But—someone interposes—such figures cannot obtain in practice: machines will not produce them. Perhaps not exactly, but machines frequently produce shapes similar to those illustrated, of which their departure from the truly circular form is only partially detected by ordinary measuring devices. A shape may thus be shown to be within permissible limits of error when it is actually outside the tolerance extremes.

As proof of this statement one may instance an experience of the National Physical Laboratory, recounted in their 1919 Report. Roller-bearing rollers shown by the mircometer to be cylindrical within a tenth of a thousand of an inch proved upon being tested by other means to be uncylindrical to the extent of one-thousandth of an inch—ten times the supposed error. The rollers were trilobate, a shape resulting from the peculiar process of lapping, to which their surfaces had been subjected in the finishing. Whilst their lobate form was not prejudicial to their use in roller bearings, between the races of which they would fit as well as true cylinders, for the purpose for which they were intended—utilisation as a cheap form of reference gauge—they were useless.

(To be continued.)

The November Nickel Bulletin gives a very informative and interesting article on heat-resisting steels. It deals with the effect of heat-treatment, with the usual forms in which these steels are available, their mechanical and physical properties, machinability, welding, and soldering, and gives much information on the applications of these steels. In addition to this article, the issue contains the abstracts and references which form a useful part of these Bulletins. Those interested can obtain a copy of this issue on application to the Mond Nickel Co., Ltd., Imperial Chemical House, Millbank, London, S.W. 1.

Alloy Cast Irons.

THE production of alloy cast irons has received considerable attention during recent years. Investigations have generally been confined to the influence of small additions of special elements, and results have shown how valuable these small additions are in improving the physical properties of cast iron. Much of the work has been carried on in the laboratory, but for a number of reasons its application on a practical scale has not made the degree of progress conditions warrant. Improvement in the properties of cast iron increases its competitive value, and enables it to be used with greater confidence for high-duty service. The high cost of production and difficulties encountered in melting and casting have been retarding influences in the greater development of alloy cast irons, but these difficulties are being overcome, and with the increasing need for materials that give adequate service under exacting conditions, the cost factor should be given a broader interpretation. At the same time, there is a potential danger to what is a hopeful metallurgical development of considerable practical assistance to the foundryman and to the engineer, stated Mr. G. S. Bell, in a paper presented to the Manchester Metallurgical Society recently, in which he gave some valuable results of practical experience with alloy cast irons, more especially those with nickel additions of between 1 and 2%. The danger he referred to lies in the tendency to claim too much and to expect too much from these alloy additions to cast iron.

With additions of nickel varying between 1 and 2%, the iron is grey throughout, and it can be machined without difficulty. The combined carbon is in a fine pearlitic state, and the graphite is split up in the dendritic form. As the nickel content is increased, the pearlitic structure of combined carbon becomes sorbitic, and with a further increase, to a content of between 5 and 7%, the structure becomes definitely martensitic, in which condition the iron is hard and difficult to machine. An increase of nickel above 7% causes the structure to change gradually, until with over 20% the iron becomes completely austenitic, with properties quite different from those of ordinary cast iron.

The more useful and important class of nickel cast irons, from many points of view, is that containing from 1 to 2% of nickel, but full advantage from the nickel addition is only possible when the basis mixture of iron is of correct analysis in relation to the casting to be poured. Nickel exerts its main influence in its effect on the combined carbon, and this influence is not affected by variations in the other constituents of the iron, with the exception of silicon, so that the two constituents—carbon and silicon—must be controlled. For maximum strength the total carbon should be low, the graphite carbon being as low as possible consistent with good machining properties. Like silicon, nickel has the effect of turning a white iron grey, thus, when nickel is to be added to a composition, the silicon contents must be correspondingly lower.

When the highest degree of strength and grain closeness are of primary importance, Mr. Bell stated that he has found it essential to first run the basis mixture into pigs, remelt these, and then add the nickel to the remelt. In adding the nickel, experiments have shown that the best results are obtained from the use of a nickel-silicon alloy containing about 90% nickel. This alloy (generally known as F-nickel) is effectively added in the form of shot. A successful method of adding the nickel is to tip the shot into the stream of metal as it leaves the tapping hole. Loss from oxidation is practically negligible, providing reasonable precautions are taken. For instance, there should be at least 6 in. of metal in the ladle before the nickel addition is made in the cupola spout: further additions are made at regular intervals, the total addition being complete when the ladle is about two-thirds full. The metal must be clean and as hot as possible. Pouring practice with nickel cast irons does not differ from the methods employed with ordinary cast iron, and it is Mr. Bell's experience that hand-feeding of certain castings is still necessary.

The use of pearlitic nickel cast iron is justified, said Mr. Bell, in cases where closeness of grain structure throughout every section of a casting, resistance to wear, and high strength are of primary importance. Experiments with cylindrical blocks of 6½ in. diameter and over, cast with nickel cast irons, in which two-thirds part nickel displaced one part silicon, have shown no appreciable change in structure throughout the section, and practically no variation in Brinell hardness from a series of tests made across the diameter. In regard to resistance to wear, Mr. Bell stated that his experience was concerned particularly with liners for Diesel engines. He referred to the two-cycle type of marine engine, the liners of which are subjected to intense wearing conditions. Many factors affect the question of wearing quality in marine Diesel cylinder liners, such as resistance to growth, uniformity of texture throughout the bore, closeness of grain, lubrication, etc. In practice, Mr. Bell had not been able to prove that nickel cast iron resists growth better than an ordinary refined cylinder iron, but it is no worse. On the other hand, nickel iron gives greater uniformity of texture, while, in regard to grain closeness and efficiency of lubrication, which are related to each other, opinions differ as to how they are related. Actual results from liners working under normal conditions were given from reports of nickel-iron liners in marine Diesel engines of the Sulzer type. A vessel equipped with a five-cylinder Diesel engine, fitted with four liners of ordinary refined cylinder iron and one liner of pearlitic nickel cast iron, was examined after doing 16,000 miles. The nickel-iron liner was found to show 30% less wear than the average on the remaining four liners. The vessel is now on another long trip, and further measurements will be made on its return to ascertain a comparison.

Experiments, carried out under working conditions, failed to show any measurable difference between pearlitic nickel iron and ordinary iron in regard to the effects of corrosion, but instances were related in which good resistance to erosive action was shown. A high strength of 18 to 22 tons per sq. in. can be regularly obtained from a test-bar 1·25 in. diameter, cast separately and machined down to a 0·798 in. B.E.S.A. test-piece, while traverse tests almost without exception exceed 4,000 lb. ultimate stress on a 2 in. × 1 in. bar broken as cast on 36 in. centres.

The effect of adding small percentages of chromium to grey cast iron increases the hardness of the iron and its tendency to chill, but in conjunction with nickel in the proportion of one part of chromium to three parts of nickel, a counterbalancing effect is produced which is beneficial because it makes the thicker and heavier sections of a casting closer in texture than with a nickel addition only, while no increased chilling effect is noticeable in the thick sections.

Reference was made to the properties of a nickel cast iron having an austenitic structure known as "Nimol," which can be achieved by alloying nickel, copper, and chromium to the basic grey iron. The approximate range of composition of this special alloy was given as follows:—

Total carbon	2.50—3.00%
Silicon	1.25—2.00%
Sulphur	0.04—0.12%
Phosphorus	0.04—0.30%
Manganese	1.00—1.50%
Nickel	12.00—15.00%
Copper	5.00—7.00%
Chromium	1.50—4.00%

This austenitic iron has very good corrosion-resisting, heat-resisting, and non-magnetic properties. The tensile strength is about the same as ordinary cast iron, its elongation is measurable, and is usually between 1·5 and 2·5% on 8 in., and it has the great advantage of a machinability equal to that of phosphor bronze. It also retains a very good consistency of grain structure under varying rates of cooling, which is distinctly useful in castings of intricate design.

Recent Developments in Tools and Equipment

The Simplex Rapid Mud Gun.

MANY attempts have been made to overcome the disadvantages of the single-cylinder mud gun in general use for stopping tap-holes. The older designs in blast-furnace plant have long been recognised as inefficient, and the cause of many troubles. The placing and adjustment of such a machine by hand is a lengthy and difficult operation, which exposes the operators to considerable risk. When it is in use the blast must be reduced, and it is impossible to work against the stream of metal. This type of gun seldom holds the amount of stopping material necessary to ensure complete stopping with one stroke of the plunger, and recharging the gun removes all support from the stopping material driven into the tap-hole, and it may be forced back into the barrel by the pressure in the blast furnace. Considerable damage may result to the machine and personnel, and, due to the formation of oxyhydrogen by the decomposition of the moisture in the stopping material by the molten iron, explosions are not infrequent. Multi-cylinder machines have been designed to overcome this difficulty; the object being to provide a reserve of stopping material capable of being used quickly when the first stopping proved insufficient. These designs, however, presented other difficulties in practice: they were unwieldy and very difficult to handle. Various devices have also been tried for automatically slewing the gun into the correct position in front of the tap-hole, but invariably these have been both cumbersome and complicated.

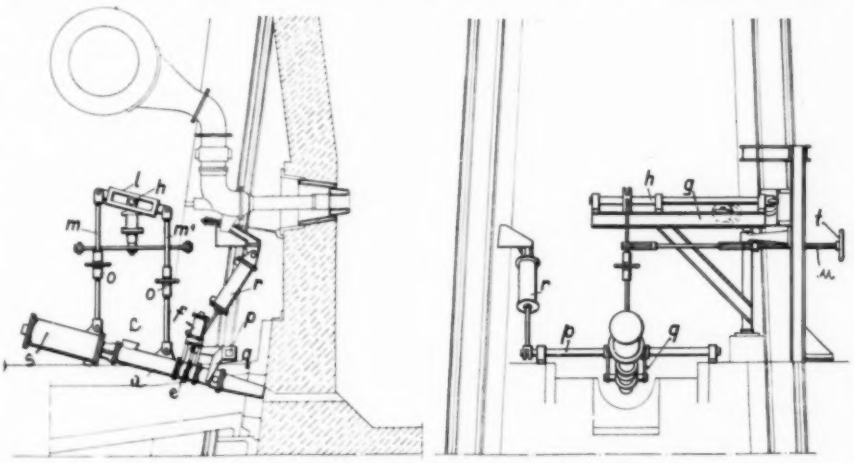
What is claimed to be a solution for these troubles is the new Simplex Rapid mud gun, constructed by Zimmermann and Jansen G.m.b.H., of Dueren, Rhineland, two elevations of which are shown in Figs. 1 and 2. It is of the single-cylinder type, and incorporates a mechanical locating device of simple and practical design which permits the stopping operation to be repeated any number of times without any risk. When the control is actuated, the piston *b* forces the plugging material from the funnel *c* into the chamber *a*. An important feature is the arrangement of the stop-slide inside *e*, between the ram and the mouthpiece, the slide being automatically operated by the control piston in the cylinder *f*.

As will be noted from the accompanying illustrations, the machine is suspended from a jib crane in the usual way, and the suspension arrangement is movable in the horizontal as well as the vertical plane. On the jib being slewed, the parallel-bar linkage is forced from the rectangular arrangement to an oblique position. This parallel bar linkage facilitates rapid adjustment in accordance with the position of the tap-hole, the nozzle being located at the correct position automatically on the machine, being swung in front of the hole. The screwed spindle *u* adjusts the parallel members, and also the movement of the machine, while the movement of the jib is effected by the slewing cylinder. The machine is also guided mechanically in the vertical plane. The shaft *h* of the jib carries at its end a lever moving a guide which facilitates vertical adjustment.

When the machine is slewed near to the tap-hole, the suitably shaped guide causes the shaft *h* to rotate, and thus to alter the formation of the parallel members. This brings about an inclination of the gun to meet the tap-hole. Then, by means of turn buckles *o*, which are provided with hand-wheels, the gun is adjusted to the correct position in relation to the tap-hole, and as long as the latter remains in the same place, there is no need to alter this setting of the gun.

The machine is forced against, and held in position at, the tap-hole in the usual manner by shaft *p*, claws *q*, and cylinder *r*. As soon as the machine is in this position, piston in cylinder *s*, as shown in Fig. 1, moves the plunger towards the tap-hole, which is closed by the stopping material being gradually forced in. The pneumatic interconnections are so arranged that the compressed air first enters the cylinder *s* and shortly afterwards obtains admittance to cylinder *f*, which lifts slide inside *e*, thus clearing the way for the stopping material into the tap-hole.

The contents of the machine are normally sufficient for stopping the tap-hole securely. If further stopping is necessary, the plunger is withdrawn, the compressed air interconnections ensuring that, before such withdrawal, the slide inside *e* is automatically closed, so as to prevent the slag stopper from being forced back. This arrangement absolutely eliminates the possibility of the stopper, followed by molten metal or slag, re-entering the gun, thereby imperilling both operators and machine. It follows that any desired quantity of additional stopping material can be charged into the machine, and further stopping for mending the tap-hole effected without danger.



Figs. 1 and 2.—Showing two elevations of the Simplex Mud Gun.

The parallel-motion mechanism is designed to permit of easy adjustment by means of the hand-wheel *i* and the screwed spindle *u*. This arrangement renders the machine adaptable to any tap-hole position, and can also be used for repairing breaks in the vicinity of the tap-hole. The valves controlling the machine can be located at any convenient place in the vicinity of the furnace, but at some distance from the tap-hole, out of the danger zone.

Frequently the closing of the tap-hole is not enough, the brickwork may be eroded and repairs must be executed. This necessitates a repetition of the stopping operation a number of times. In every instance, however, it is advisable to operate the gun so that the charge is forced in slowly to ensure a uniform stopping and preferably a mushroom finish on the interior of the furnace. It is occasionally

advisable to drill the hearth to the right and left of the tap-hole with the object of ascertaining whether the thickness of the brickwork is still adequate. The stopping material can then be injected through these holes to repair any cavities that may have been formed, and, because of the ease of adjustment, this machine is particularly suitable for such a purpose.

New Low-temperature Electric Furnace.

CONSIDERABLE differences of opinion exist as to the type of heating best suited to low-temperature work. Oil, salt, and lead baths frequently used for tempering and other forms of low-temperature heat-treatment, while offering advantages in regard to atmospheric control and uniform transfer of heat to the charge, have a number of disadvantages. Thus, for instance, there is no control of the

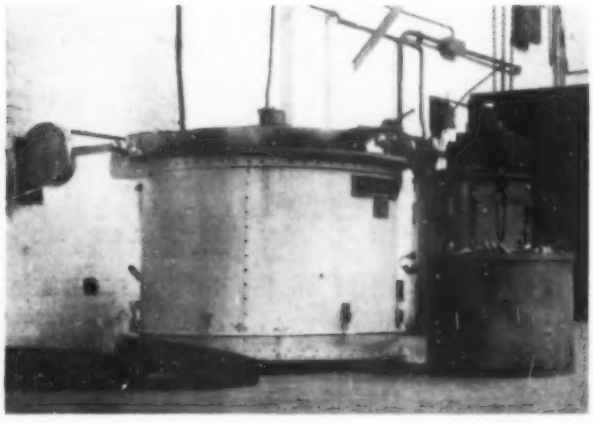


Fig. 1.—Low-temperature Electric Furnace.

rate of heating of the charge, and preheating is frequently necessary, and additional cleaning of the articles so treated is usually necessary. In the plain oven or furnace used for heating parts up to 600° or 700° C., although simple in operation, the heating often lacks uniformity, and is slow, due to the fact that at such low temperatures heating depends upon convection, but in a suitably designed oven, and by means of a specially designed fan, low-temperature heating becomes rapid, and uniformity is assured.

A new low-temperature electric furnace with these advantages, designed by Messrs. Wild-Barfield Electric Furnaces, Ltd., in which air is circulated under pressure, is shown in Fig. 1. The air is driven by a centrifugal fan over the heating elements, and drawn down through the cold work which has to be heated. In heating the work—which is generally placed in a perforated container made from non-scaling metal—the hot air is cooled so that if a thermocouple is placed immediately below the work, and a second thermocouple is situated in the air stream immediately it has left the heating elements, a great difference of temperature will be recorded after the cold charge has been introduced. Gradually, however, as the charge absorbs heat the difference becomes less marked,

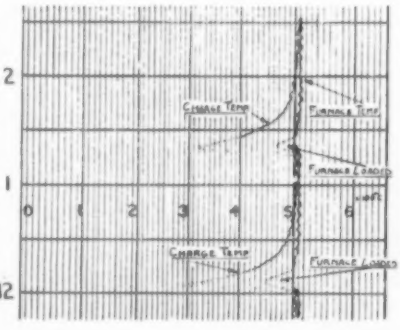


Fig. 2.—Part of Temperature Chart.

and when both thermocouples record the same temperature uniformity of heating through the charge has been obtained and the work is ready for removal.

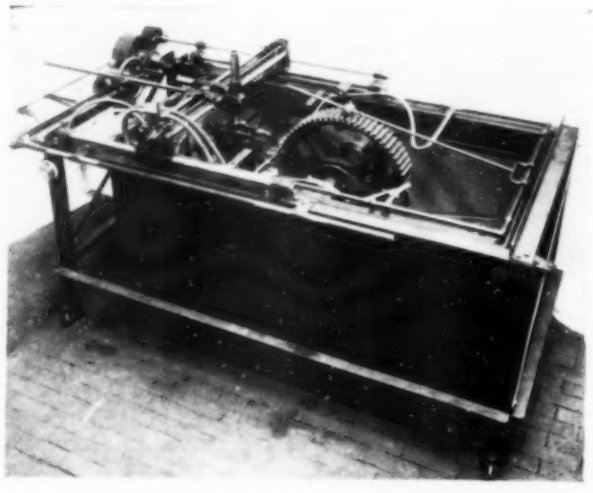
Incorporated with this new equipment is the Wild-Barfield-Foster patent charge progress recorder, which not only records the temperature as described, but also automatically controls the temperature. The importance of close control in heat-treatment is generally appreciated; with nearly all low-temperature heat-treatment, however, it is particularly important, and the value of this recorder will be seen on reference to the temperature chart reproduced in Fig. 2, which shows that at 510° C. the variation is only ± 2° C. Cyclic variation is equally important when dealing with this type of furnace, and that of the charge at 500° C. is only 2° C., as will be noted.

The charge progress recorder is an instrument of robust construction, and of the type usually installed in hardening shops for ordinary temperature records. The record itself is made in two colours, black representing the progress of the charge and red the temperature of the furnace. Numerous interesting features are embodied in this charge recorder and automatic temperature control, as well as the low-temperature electric furnace, and a demonstration of the entire equipment can be arranged for anyone interested on application being made to the manufacturers.

New Shorterizing Machine.

SHORTERIZING is a process by which wearing surfaces of hardenable iron and steel articles can be locally hardened. The process is intended to produce a hardened zone of metal sufficient to materially increase the serviceable life of the part submitted to treatment, and to do it uniformly and without distortion; and this is effected by means of mechanically controlled heating and quenching media. Experience has proved that when correct materials are used this process increases the life of surfaces subject to abrasion, and the treatment may be applied to either forged or cast steels, cast iron, and malleable cast iron.

The hardening is effected by mechanically operating an oxy-acetylene flame suitable in size and degree to the area under treatment, over the surface to be hardened, and by following this with a cooling jet to quench the heat imparted to the surface. This cooling jet follows immediately behind the heating flame as it traverses the surface of the metal, so that quenching takes place immediately the steel is brought to the critical temperature.



New Shorterizing machine.

One of the applications of this process is in the treatment of gear teeth. Developments in the process have made it possible to produce a uniform high Brinell hardness on surfaces of teeth subject to wear, without in any way injuring the core strength. The process can be applied with equal success to either large or small gears, and a new

machine, which is shown in the accompanying illustration, has recently been designed with the object of simplifying the process, while at the same time giving a high degree of control.

The gear to be treated is readily mounted on an adjustable spindle and placed in bearings so arranged in the tank that the wheel can be wholly or partially immersed in the water, according to requirements, during the time of treatment. Improvements in the new machine enable a larger range of work to be treated, and as the weight of the operating heat is reduced, the controls and adjustments are rendered more delicate and sensitive for precision work. In addition, the facilities for cooling have been improved by providing for a wider range of cooling adjustments.

A new type of gas-control valve has been introduced in this machine which incorporates an improved method of trip for extinguishing the flame at the end of the operation. These improvements have been made as a result of practical experience in the application of the process, and have been incorporated in the design of the machine with the object of improving the facilities for the successful treatment of gears by this process. Further information of this machine can be obtained from The Patent Gear and Metal Hardening Co., Ltd., 69, Horseferry Road, Westminster, S.W. 1.

Manufacture of Steel in the Coreless Induction Furnace.

THE fitness of the coreless induction furnace of large type for the manufacture of steel is discussed by F. Pölzguter in *Stahl und Eissen*, vol. 51, No. 17, 513-520. The design and electrical equipment of two furnaces (capacity of 500 kilogs. and 1,000 kilogs.) and the method of preparing the crucible are described. For comparison, data are given on the cost of lining, energy consumption, production per hour, and loss in components of the two induction furnaces and two arc furnaces of the same capacity. Two heat-balances show the various losses in heat for the two types of furnace.

The pros and cons of the induction furnace for refining pig iron are fully discussed. The good results obtained with furnaces of laboratory size cannot be expected from the large type. Because of the life of the lining, this type cannot be worked with a high surplus of energy necessary for obtaining a vehement agitation of the bath. The refining action is by far less than that of the converter and the open-hearth furnace. On the other hand, the induction furnace is well suited for finishing steel (carburisation, desulphurisation, deoxidation). In the present state of affairs it is the best melting unit, especially for carbon-free alloys.

Precipitation Hardening of Steel.

IN a consideration of the precipitation hardening of steel by means of titanium, published in the July issue of *Kruppsche Monatshefte*, R. Wasmuth states that in view of the high cost and the poor machining properties of steel containing a high percentage of titanium, for practical purposes a maximum content of 3% is advisable. As the solubility of titanium in iron is 6·3% for obtaining precipitation hardening at lower titanium contents, the addition of a further alloying element is necessary, which, though soluble in the basis metal, does not dissolve titanium. Silicon was found to comply with these requirements. Alloys containing Ti from 1 to 7, Si from 2 to 3, and Mn about 1%, after quenching and annealing, showed about the same increase in hardness—viz., 125%. From further series of experiments the following conclusions can be drawn: (1) The height of the quenching temperature is of importance only with the higher titanium contents; the same is the case with the quenching medium (water, air). (2) In general, with a definite annealing temperature the maximum hardness is obtained the sooner the higher the titanium content, and with a definite titanium content, the higher the content of the additional element. (3) Precipitation hardening can also be obtained by a plain annealing treatment—that is, without quenching. The annealing time, however, is remarkably longer, and with the higher titanium contents the maximum hardness is no more obtained. (4) The coarse texture associated with high quenching temperatures can be refined by alloying manganese, nickel, or chromium. (5) Besides silicon, nickel has also a favourable influence; manganese, chromium, and aluminium have no practical effect; carbon impairs the hardness by the formation of insoluble titanium carbide. (6) The precipitation hardening is decreased with decreasing cooling rate from high temperatures. With increasing content of both titanium and the additional element, the critical cooling rate is displaced to lower values.

From the change in hardness, electrical and magnetic properties the author concludes that the first increase in hardness after annealing is not due to the precipitation of titanium in a highly dispersed form, but to changes occurring within the solid solution.

Heating Control Reduces Steel Forging Failures.

FAILURES in forging steel may result from many factors, but the heating of the metal has a very important influence. It is only by exercising care in heating that burning, a serious and more common fault than is usually realised, and scaling, which is generally regarded as inevitable, can be overcome. The advantages accruing from control in this respect are discussed by Dr. D. W. Murphy and W. E. Yoming, in a bulletin of the Department of Engineering Research, from results of investigations they have carried out at the University of Michigan.

"Burning" of steel occurs in a furnace when the temperature reaches a certain point, and this burning temperature has been found to be lowered when free oxygen is present in the furnace atmosphere. The danger resulting from burned forgings is that the damage, invisible to the naked eye, may be very serious in the centre of the piece, and is only detected in broken parts by the microscope, which shows the weakened structure. The authors found that more accurate temperature control than is usually practiced, and the use of a slight over-supply of fuel to ensure combustion of all free oxygen, will raise the burning point and diminish the danger.

Poor quality of finished products from scaling of heated steel surfaces is much greater than is commonly recognised. Its formation results in loss of metal weight, and if removed it involves extra labour costs, while if left and pounded into the metal it causes weak spots, as well as being injurious to dies. Scaling losses increase as the heating temperature rises, and become very great at the melting points of the scales. Presence of sulphur in fuels used is also an influential factor.

The authors suggest that total avoidance of scale is possible by firing with a considerable excess of sulphur-free gas to use up all free oxygen, since scale is chiefly iron oxide. In general commercial practice, with present furnaces, they point out that this would be uneconomical, and suggest the need of new furnace designs.

Age-hardening of Carbon Steel.

DATA on the influence of ageing upon the properties of steel containing 0·98% carbon, 0·19% silicon, 0·43% manganese, 0·026% phosphorus, and 0·01% sulphur, are given by S. Steinberg and W. Subow in July 16 issue of *Stahl und Eissen*. The steel was quenched in water at 750° C. Rockwell hardness and transverse strength were determined after ageing at room temperature 75°, 100°, and 125° C. respectively. The transverse strength increased with the exception of the sample aged at 75° C., with which it remained the same. The hardness increased also, and then slowly decreased with the samples aged above room temperature. The increase in hardness was accompanied by a decrease in length, with which the samples aged above room temperature tended to a limit value of about 40% of the increase in length after quenching.

Soda Ash as a Desulphurising Agent.

Beneficial Effects on Iron and Steel Products.

The value of alkalies in removing sulphur from molten iron has long been appreciated; as early as 1867, Horsley, of Derby, called attention to their beneficial effect, and since then many proprietary products with alkaline ingredients have been marketed as desulphurising agents. The action of alkalies on molten metal has been further demonstrated as a result of an exhaustive investigation by the research staff of Imperial Chemical Industries, Ltd. The results of this investigation show that a 50% to 60% reduction in the sulphur content of the metal can be effected by the use of relatively small proportions of soda ash.

The use of soda ash as a desulphurising agent materially assists in overcoming one of the most important problems of modern foundry practice—the control of sulphur impurity in cast iron. Low sulphur content in pig iron does not infer a low sulphur content in the finished castings unless high-quality coke is used, and only a limited proportion of scrap remelted in the course of production. The necessity of reducing the sulphur content to meet the requirements of the modern specification has therefore imposed restrictions on the foundry industry in the choice of raw materials and thereby increased the cost of manufacture. The problem is of special importance when the metal is required for conversion into steel by the Tropenas converter.

In ordinary foundry practice the desulphurisation is effected by placing the required amount of dry soda ash on the bottom of the ladle and then tapping out the metal from the cupola at as high a temperature as possible, and preferably at 1400°—1450° C. A vigorous but not violent interaction between the metal and the alkali takes place with rapid evolution of carbon dioxide and formation of sodium sulphide and other sulphur compounds. The main reactions involved may be represented by the following equations:—

$$Na_2CO_3 + \begin{matrix}MnS\\FeS\end{matrix} = NaS_2 + CO_2 + \begin{matrix}Mn\\Fe\end{matrix}$$

Sod. Carbonate (Soda Ash).	Manganese Sulphide. Iron Sulphide.	Sodium Sulphide.	Carbon Dioxide.	Manganese Iron.

The vigorous evolution of carbon dioxide maintains the molten mass in a state of agitation and ensures intimate contact between the metal and the alkali reagent. When the molten metal becomes quiescent a thin soda slag, which contains sodium sulphide and other sulphur compounds, collects on the surface, and in cases where the cupola is tapped intermittently the subsequent batches of metal pass through the slag and thus cause further agitation, which increases the efficiency of the removal of the sulphur. When the ladle is full a quantity of ground limestone is thrown on to the slag and rabbled into it. The limestone absorbs the thin alkaline layer and causes the formation of a thick slag which can be raked off without difficulty. The thickened slag should be removed as completely as possible, and the desulphurised iron may then be cast in the usual way or run into the converter if it is required for the making of steel.

It will be noted that the process of desulphurising by means of soda ash is simple and is also inexpensive. It can be applied at various stages in the manufacture of steel ingots, steel castings, refined pig iron, and iron castings of different grades—*e.g.*, grey iron, white iron, malleable iron, and iron alloys—and no important changes in the normal foundry routine are involved. The only reagents required are the ordinary commercial grades of soda ash in powder form, and ground limestone, and the cost is about 1s. 6d. per ton of metal. The reduction of the sulphur content of the metal prevents the cracking of steel castings. Moreover, it is accompanied by a definite improvement in the physical properties of the metal and by the almost complete elimination of non-metallic inclusions of sulphides, oxides, etc.—an effect of special importance in foundries producing castings which are to be submitted to a hydraulic test or exposed in use to the action of corrosive liquors. The cost of manufacture is reduced, because products which would normally demand the use of high-quality raw materials can be made by the use of pig iron and coke of higher sulphur content and a greater proportion of metal scrap.

The results of these laboratory investigations and tests carried out under practical foundry conditions are contained in a booklet recently issued by the Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1, who are prepared to give advice and technical assistance to interested firms.

Good Lighting—An Economic Necessity.

High output of the best work depends fundamentally on the high efficiency of the human factor. Progressive employers generally recognise that this efficiency depends upon clean, bright workshops, ample ventilation, and, among other factors, good lighting has an important influence. Artificial illumination particularly plays a much greater part in output than many people imagine. There is a definite relationship between scientific factory lighting and overall works efficiency in regard to output achieved without waste of human effort, energy, and health, time, and material, and careful tests show that production alone can be increased by from 10 to 20% by providing good lighting at an increased outlay that amounts to no more than 1 to 2% of the wages account.

In too many factories and workshops the artificial illumination consists merely of lights hung in positions where they seem to be wanted; little attention has been paid to their distribution, their height, the glare they produce, and several other factors which affect vision, and, therefore, speed, accuracy and physical fitness of the worker. Considerable improvement can be effected in many cases simply by the modification or substitution of existing shades. The initial cost of such a change is so small, and the maintenance so negligible, that it is a matter of perpetual wonder that it is not generally made.

With scientifically considered positioning of lamps, their correct distance apart and height from the floor, and the use of suitable intensity, and a type of shade or reflector that will cut out glare, even distribution and a shadowless illumination can be obtained throughout individual shops for workers and machinery, instead of spots of light on single machines, and all-round gloom or patchy lighting complicated by reflected light from metal parts—all of which are avoidable factors contributing to works accidents.

Extensive study by illuminating engineers skilled in planning lighting layouts for gas and electricity has established the very best arrangement of lighting for any type of workshop. They can define without hazard but with precision the exact standard of illumination that should be adopted for operations even of the most critical or delicate kind to be carried out in any workshop, and, if attached to any electricity or gas undertaking, their services in advising on new work, or the improvement of existing lighting, are available to any employer or manager free of charge.

The offer is one which all industries cannot afford to neglect, as good lighting not only aids production both as to quality and quantity, but is kind to the eyesight of workers, reduces accidents, creates a cheerful environment, facilitates supervision and the maintenance of discipline, and encourages cleanliness and order.

Mining Laws of Great Britain.

Great Britain has never had a basic mining law such as is in force in most foreign countries. This lack may be due to the fact that, with the exception of gold and silver, all metals or minerals belong to the owner of the surface land. Even with respect to the precious metals, gold and silver, which are not abundant in Great Britain, the right of the Crown, though still technically acknowledged, is not always insisted upon. All other metals and minerals are vested in the ground landlord, who may sell, lease, or otherwise convey them. The State has little to do with the mining industry except in regulatory and judicial matters. The Government must settle controversies and provide for easements, rights of way for railroads, roads, and canals, or, in general, effect the same control that it exercises over other industries.

As mining was carried on in very early times in England, of necessity a certain legal procedure came into existence, which, in effect, was little more than a private contract between the owner of the mineral (whether an individual or the State) and the miner. The nature of such contracts, of course, has changed radically with the changed relations between classes, as England has developed from the feudal into the modern state. From the medley of ancient procedure and custom a concession system of mining in its simplest form has evolved.

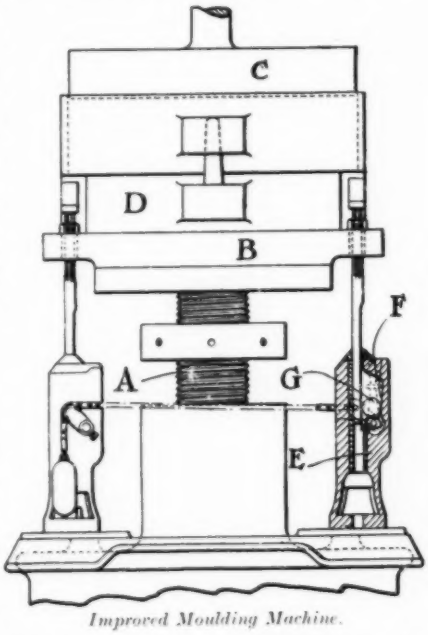
Numerous bibliographic references to the mining laws of Great Britain are given by E. P. Youngman in Information Circular 6516, which may be obtained from the United States Bureau of Mines, Washington, D.C., who discusses such subjects as rights of foreigners, property in mines, prospecting, leases and licenses, and rents and royalties. The reorganisation of the coal industry of Great Britain in conformity with the Coal Mines Act of 1930 is discussed.

Some Recent Inventions.

Moulding Machine Improvements.

THESE improvements refer to moulding machines of the type in which the mould is formed by direct compression exerted between a presser head and member acting on the pattern plate. Incorporated with the machine is a piece of mechanism forming a non-return device for use in conjunction with a stripping plate, a moulding box, or other part which may be required to accompany the pattern during the pressing of the mould, but not to return with it. This non-return device is particularly useful in cases where the mould is made by pressing the pattern upwards into the box, and where the pattern is a deep one.

The device consists of a pillar or group of pillars arranged to be moved forward with the stripping plate or moulding box, and to be released from its driving member and engaged by a stationary wedging device at the commencement of the return movement. This wedging device consists of a tapered chamber through which the pillar passes, and in which is located a roller having a tendency to move towards the narrow end of the chamber, where it wedges between the chamber wall and the pillar. The forward movement of the pillar counteracts this wedging tendency, but when a reversal takes place engagement results.



Improved Moulding Machine.

The accompanying illustration represents an elevation showing a section of the non-return device, and the column A, which is power operated, lifts the pressure plate B and its burden, so that the presser-head C presses the sand around the pattern on the pattern plate D. In stripping, the patterns are lowered clear of the mould.

Through holes in the pressure plate B pass four pillars or stools having adjustable nuts on a threaded portion, which ensure that the pillars are lifted during the upward movement of the pressure plate. Within the pedestals E are incorporated the non-return mechanisms, the moving parts being contained by the chambers F, through which the pillars move on guide faces. Inside the chambers are located rollers G, which on movement towards the narrow end of the chamber act as wedges between the inclined walls and the pillars. The upward movement of the pillars counteracts this wedging action, but when the reversal takes place, due to the action of gravity upon the pillars as the pressure plate B is lowered, engagement takes place, and the movement of the pillars is arrested.

Within chamber F are releasing cams H, which are carried on spindles supported by bearings in the pedestal frame. These spindles are extended to the front of the machine, and handles and arms are fixed on them. Chains are fixed to these arms which pass over grooved arms carried upon extensions of the two rear spindles, and suspended weights hold the chains taut in this position. Hand operation of the handles causes cams to rotate sufficient to move the rollers G out of the wedging positions, and the pillars being released fall to their original position below the level of the pattern plate to allow a fresh moulding box to be set in position.

349,173. THE BRITISH INSULATED CABLES, LTD., of Prescot, and T. W. BULLOCK, of Rainhill, Lancashire, patentees; R. L. Cleaver, agent, Cable Research House, Silver Street, London, W.C. 1. Accepted May 28, 1931.

Wire Heating Furnace Improvements.

WHEN coal, coke, raw producer gas, or oil are used as the fuel in wire-heating furnaces, it is necessary to use the type of furnace in which muffle tubes are provided for passing the wire or rod through, and an inert gas is passed through the tubes with the object of reducing scaling. One of the objections of this type of furnace has been the difficulty of accommodating an adequate number of muffle tubes in such a way that a regular and uniform heat is maintained in them.

A recent improvement in this type of furnace has for its object the provision of several rows of muffle tubes, extending the full length of a heating chamber, and occupying the whole width, having division walls. Resting in the side walls, and on the division walls at equal distances apart, are placed rectangular bearer bricks, of desired length, touching each other, end to end, forming continuous supports, across the heating chamber for the tubes.

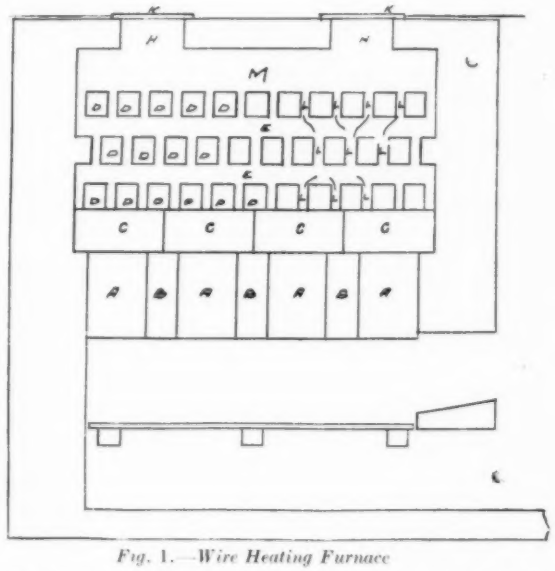


Fig. 1.—Wire Heating Furnace

A second row of tubes is placed over the first, but raised by supports, so that the products of combustion can pass between the rows. The cross-section of a furnace constructed with three rows of tubes is shown in Fig. 1. The longitudinal heat chamber which extends the whole length of the furnace is shown at A. Into this chamber the products of combustion pass from the firebox shown below. The divisional walls B B B support the rectangular bearer bricks C C C C, which in turn support the muffle tubes D, three rows of which extend the full length of the furnace and are separated by spaces L. The passages E E, between the rows, are to enable the products of combustion to surround the tubes as they ascend to the outlets H H to be carried away to a suitable flue.

The effect of this improvement is to cause the heat to completely envelop the tubes and, with the aid of dampers K, the temperature of the furnace will be under control. The method offers facilities for augmenting the capacity of a furnace of this type.

349,671. H. B. BLYTHE, of Hillsborough, Sheffield, patentee. Accepted June 4, 1931.

Reviews of Current Literature.

Faraday's Metallurgical Researches.

FEW great men have received a more slender educational equipment than Michael Faraday, but none have eclipsed the importance and varied character of his investigations. His greatest achievements were due to his investigations in electricity, of which much has been written, but with the exception of papers he prepared with James Stodart and presented to the Royal Institution and the Royal Society, little reference has been made to his researches in alloy steels. This has now been remedied by the work of Sir Robert Hadfield, who by permission of the Managers of the Royal Institution and the Director of the Science Museum, South Kensington, subjected the surviving specimens of Faraday's work on "steel and alloys" to an exhaustive examination.

When it is remembered that Faraday discontinued his researches in this field about 107 years ago, at the age of about 33, the revelations of Sir Robert, in regard to the specimens examined, are remarkable. The facilities for metallurgical research, which have come to be regarded as essential to modern investigations, were, of course, not available to Faraday, and his papers convey very little information regarding quantative chemical analysis. The box, labelled "Steel and Alloys," which had been in the storeroom of the Royal Institution for over a century, contained 79 specimens, and the whole weighed only about 8 lb. Information regarding the composition of individual alloys was lacking, although the alloying elements and compounds employed by Faraday were given in his papers. Despite the fact that the specimens were small and of unknown composition, portions were removed from each one for investigation without completely destroying the valuable relics.

The results of the investigation, which are published in this volume, constitute a remarkable tribute to the work of Faraday, and form a valuable contribution to the history of science. The author claims that they definitely establish that Faraday was the first to engage in systematic research concerning the preparation of alloys of steel. This is indeed a testimony, for the author writes from a metallurgical experience of fifty years, the whole of which time has been devoted to alloy steels.

Faraday's association with steel is conveniently considered by the author under five headings. First, his examination of wootz or Indian steel; second, the series of experiments on the alloys of steel; third stage represented by Stodart and Faraday's paper, "On the Alloys of Steel"; the fourth represented by experiments on a large scale carried out at Sheffield by Faraday's representative at Messrs. Sanderson's works; and the fifth stage embraces the experiments with alloys of steel and rhodium, iridium and silver, at the works of Messrs. Green, Pickslay and Co., of Sheffield.

It is very clear that Faraday was imbued with the idea of a systematic investigation of steel alloys, and that he would never have consented to spend so much time and labour on this research if he had not believed in the possibility of obtaining valuable new materials by this means. The fact that the immediate practical application of his researches were not successful was no reflection upon Faraday, because the steel industry had not advanced sufficiently to take full advantage of his work. It has been left to later workers with improved methods to show the full extent of the possibilities of alloy steels, and even to-day with our greater facilities, we have not finished exploring the field which Faraday opened.

Sir Robert has succeeded in determining the composition and properties of the majority of the specimens, from which he has obtained much useful information. In addition, a most interesting as well as informative account is given of early metallurgical workers, and, following an appreciation of Faraday's work, he devotes much space to a consideration of the later developments of alloy steel. This volume is not only valuable as a contribution to the history of science, but also to the progress of metallurgical research in the alloy steel field.

By Sir Robert A. Hadfield, Bt. Published by Messrs. Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price 21s. net.

Plasticity.

Mechanics of the Plastic State of Matter.

THE great increase in the variety of metals and alloys which have been developed to meet the needs of modern industrial requirements, has made the study of their characteristics and behaviour of vital importance. It was supposed that machine parts were stressed only elastically when in operation, and the theory of elasticity has gradually been developed into an exact part of mechanics, which is the foundation for the design of engineering structures. It has been found, however, that structural or machine parts may assume a permanent or plastic deformation, which may lead to rupture and failure through fatigue.

A more satisfactory understanding of the plastic state of engineering materials and of the conditions of rupture has been reached since the constitution and the crystalline structure of metals and alloys, the mechanical and thermal history of metallic bars and sheets, from the beginning of the casting of the ingot to the last annealing of the finished product, and the mechanical properties of metallic single crystals as special objects of investigation have been carefully studied from a broader physical standpoint.

Considerations of the plastic state of metals and alloys are of increasing interest to many branches of engineering. More accurate control of the various mechanical processes involved in forming metals is becoming increasingly necessary. The designer, in addition to possessing a more exact knowledge of the limiting conditions of stress, in his machine parts, will have to consider the possible change in shape of those parts exposed to long duration of stressing.

There is a dearth of information on plasticity, and the publication in English of this work by Dr. Nàdai will meet a special need. Its publication has only been possible as a result of arrangements made by four American engineering societies for the production of a series of books adjudged to possess usefulness for engineers or industry, but of limited possibilities of distribution.

The work deals with the plastic state of matter in its widest sense, but special reference is made to metals and mechanical engineering problems. It is appreciated that many metals and alloys flow like soft wax under pressure, but the mechanism of plastic deformation which takes place in the crystal lattice of these materials is not yet fully known; typical phenomena likely to occur in combination with plastic flow include parallel displacements of the elements of the crystal lattice, the formation of twins, the change of positions of atoms occurring because of agitation of atoms due to heat, and the breakdown of structure occurring, often quite gradually, under an increasing load.

It may be some years before the importance of the information contained in this book is realised and applied in a systematic way to mechanical constructions, but as knowledge of plasticity becomes more widespread, its influence on the design of all forms of mechanism and structural work will be better appreciated. Dr. Nàdai is an authority on the subject, and his work is already well known, especially on the Continent. The publication of the English translation renders a valuable service to engineers and designers and the American engineering societies, who are responsible for its production, as well as the publishers, are to be congratulated on the production of a work of quality. W. A.

By A. Nàdai, Dr.Ing., assisted by A. M. Wahl, M.S. Published by McGraw-Hill Publishing Co., Ltd., Aldwych House, London, W.C. 2. Price 30s. net.

Business Notes and News

Large Vessel to be Built at Barrow.

With reference to the announcement that an order for a repeat of the *Monarch of Bermuda* had been placed with Messrs. Vickers-Armstrongs, Ltd., we are informed by the latter firm that the ship will be built at their Barrow works. The Company opened the Naval Yard at Walker-on-Tyne when they received the order for the *Monarch of Bermuda*, in view of the fact that it would have been physically impossible to guarantee the delivery of the *Monarch of Bermuda* by the contract date had the ship been built at Barrow owing to the amount of work in hand in Barrow at that time.

We understand the Naval Yard, at Walker-on-Tyne, will be maintained as an operating shipyard, ready to be opened at a suitable opportunity. The Company have every desire to reopen the yard when the state of the industry justifies them in doing so, but it is obvious that under present conditions it would be most uneconomical to endeavour to keep two yards in part occupation.

Commander Craven informs us that the new ship will provide employment at Barrow for an average of at least 2,000 men for 15 months, and, owing to the fact that the firm have all drawings and patterns in their possession, an immediate start will be made. In addition to the men employed at Barrow, there will, of course, be large numbers employed in executing the main propelling machinery for the ship—which will be provided by the General Electric Co., of Witton,—and in the manufacture of the various auxiliary machinery, furnishings, etc.

Worm Gear Efficiency Improved.

In our October issue we published test results made at the National Physical Laboratory on a "Holroyd-Walker" worm gear, which established a world record in worm-gear efficiency. Since then further experiments have been carried out at the National Physical Laboratory on the same type of gear, with the result that efficiencies up to and over 98% are observed in the N.P.L. report on the gear.

The particular pair of gears tested were the same as in the previous test as regards ratio, centre distance, materials, lubricant, etc., with the sole exception that the conditions of tooth contact between the worm and wheel were altered.

The test results are given in the accompanying table,

R.p.m. of Worm.	Horse-Power.	Observed Efficiency.
1030	13.8	97.5%
1520	20.4	97.5%
1035	24.3	97.7%
1530	36.0	97.8%
1015	33.7	97.6%
1500	49.8	97.7%
1000	43.0	98.0%
1500	64.5	97.8%

from which it will be seen that the efficiency again reaches its maximum under the maximum test load, indicating the remarkable capacity of the Holroyd-Walker tooth form for sustaining heavy loads, and for maintaining the oil film. Under maximum power the loss of input power is 2%, which indicates a low temperature rise and rate of wear in this type of gear.

Automatic Load Indicator on Derricking Jib Cranes.

Attention is drawn to the Home Office Order, which came into force on November 1, in connection with the Building Regulations in respect of Cranes used in certain Building operations having a fixed Jib or a Derricking Jib. This Order calls for an automatic indicator to be fitted to all such cranes (with certain date reservations) of a type approved by the Chief Inspector of Factories. It is laid down in the Home Office Order that all such indicators shall show clearly to the driver or person operating the crane when the load being moved approaches the safe working load of the crane at any inclination of the jib, and shall also give an efficient sound signal when the load being moved is in excess of the safe working load of the crane at any inclination of the jib.

The only indicator on the market that has been approved by the Chief Inspector of Factories is the Vickers-Nash Safe Load Indicator, which is manufactured by Messrs. Vickers-Armstrongs, Ltd., at their Dartford Works, by the use of which a practical certainty is now available instead of a doubtful judgment of a crane driver or his "slinger" as to whether a given lift may be safely undertaken.

Birmingham Furnace Firm Make Agreements with American Firms.

Agreements of far-reaching importance to all concerned with heat-treatment have been entered into by Messrs. Birmingham Electric Furnaces, Ltd., of Erdington, Birmingham. They have made an agreement with The Electric Furnace Co., of Ohio, U.S.A., which provides for the fullest technical information, designs, and patent rights. This American firm is one of the pioneers of electric furnace work in the United States, and the originator of many types which have since come into general use because of their sound, robust, and efficient designs and constructions. This firm is well known for its roller hearth, and counterflow carburising and annealing furnaces, used extensively in the automobile and other industries, while, of more recent introductions, a new type close-mesh cast-link conveyer furnace and a semi-continuous nitriding furnace have attracted considerable attention. The Birmingham Electric Furnaces, Ltd., now have the rights of the American firm's patents in Europe and the British Dominions, while The Electric Furnace Co. have the rights of "Birlee" patients in the United States and Canada.

By another agreement this Birmingham firm have the patent rights in Europe and British Dominions of C.I. Kayes, Inc., Providence, R.I., U.S.A., respecting their "Certain Curtain" method of atmosphere control. This method enables the heating of high-speed and other steels to be effected without scaling or decarburisation, and in its completeness of protection and exactitude of regulation it is claimed to be superior to other methods.

These arrangements refer only to technical information and patent rights, and do not in any way affect the administration of Birmingham Electric Furnaces, Ltd., which retains its own individuality as a British concern, producing furnaces which are British-made throughout.

British Selling Rights of German Furnace.

We are informed that an arrangement has been entered into between G. W. B. Electric Furnaces, Ltd. (Gibbon Bros., Ltd., and Wild-Barfield Electric Furnaces, Ltd.) and Demag-Elektrostahl, G.M.B.H., Düsseldorf, whereby G. W. B. Electric Furnaces, Ltd., will have the sole selling rights for Demag electric aluminium melting furnaces in the British Isles. It is of interest to note that these furnaces are at present made up to a capacity of about two tons and an input of 500 k.w.

America Concentrating on Research.

The magnitude of technical laboratories in the United States was emphasised by Professor H. G. Taylor, who for some time has been associated with Princeton University, United States, in an address in Manchester recently. He believed it was in the extent to which the United States paid attention to scientific research that the greatest differentiation would be found between that country and Great Britain. Special mention was made of the laboratories of the Bell Telephone Company, at which there were 2,000 university-trained men. He asked himself the question, Did so much expenditure on research pay? In attempting to find an answer, he asked what were the relative standards of American and of British industry. He could not answer that from every point of view, but he was quite sure that in those industries in which chemistry played a great part dozens of new developments had been initiated by the United States.

Replacing Foreign Products.

The reference in the report of the Sheffield Steel Products Company to their scheme for manufacturing products usually imported into this country is of considerable interest. Providing the demand is found to be sufficiently large, this firm purpose starting to manufacture such articles. The directors are to be commended for their initiative and courage as considerable expense will be incurred in the preparations for such a venture. According to the report, the board have been able to transplant five new lines of business, giving new employment in Birmingham and Sheffield, and they have every confidence that new ventures in progress will prove profitable before long. This company is a combination of many small firms that specialise in files, magnets, engineers' tools, cutlery, as well as many other products. This idea might well be extended so as to cover a wider range of articles which are imported in large quantities, and with care in selection, together with good organisation, considerable profit would ultimately result.

Some Contracts.

The Cleveland Bridge and Engineering Co., Ltd., of Darlington, have been awarded a contract by the River Wear Commissioners, Sunderland, for a bridge at South Dock, at a contract price of £25,000.

Henry Simon, Ltd., of Cheadle Heath, Stockport, have received an order for grain-handling plant for the Danish port of Esbjerg. The order, which is far a travelling pneumatic grain-discharging plant, with a capacity of 120 tons per hour, has been placed by the Jutland Co-operative Provender Supply Association, of Copenhagen.

Batteries, Ltd., of Redditch, have been awarded a contract for the supply of "Nife" nickel-cadmium alkaline batteries for mining electric locomotives for service in Russia.

The Metropolitan-Vickers Electrical Co., Ltd., have received an order for an exhaust turbo-electric auxiliary drive for a new vessel being built by Workman, Clarke and Co., Ltd., for the Standard Fruit and Steamships Corporation of New Orleans. This auxiliary drive is designed to deliver 1,560 shaft horsepower to the propeller at 90 r.p.m., and the turbo-alternator will, in addition, supply a general ship load of about 170 k.w.

The Mining and Industrial Equipment, Ltd., of London, have received orders from Australia for a Raymond pulveriser for grinding hydrated lime; from Rangoon for a No. 3 "Impax" pulveriser; from Rhodesia for an 8-ft. by 60-in. Hardinge ball mill, for grinding lead-zinc ore.

Messrs. Anemostat, Ltd., of Glasgow, have received the order for a ventilation and electrical heating system for the new Parkhead garage for the motor omnibuses of the Glasgow Corporation Tramways Department. The arrangements for exhausting the engine fumes of the vehicles and the electrical thermal storage equipment are to be supplied by Bastian and Allen, Ltd., of 26, Cross Street, London, N. 1.

Sir Robert McAlpine and Sons (London), Ltd., have secured a contract from the London and North-Eastern Railway Co., estimated to cost approximately £500,000. It involves the widening of the railway from Gidea Park to Shenfield, a distance of about seven miles. The reconstruction of 15 bridges will be entailed, and it is estimated that about 1,200 tons of steelwork will be required, in addition to the steel required in the permanent way.

Messrs. Vickers-Armstrongs, Ltd., have received an order for a repeat of the *Monarch of Bermuda* for Messrs. Furness, Withy and Co., Ltd. The vessel is to be built at Barrow, and the main propelling machinery will be provided by the General Electric Co., of Witton.

Messrs. Lithgows, Ltd., of Port Glasgow, have received an order for a cargo steamer of 6,500 tons from Messrs. H. Hogarth and Sons, of Glasgow.

Messrs. Austin and Son, of Sunderland, have been awarded a contract for two colliers by the London Power Co. The Burntisland Shipbuilding Co. have received a contract for two others. The vessels will each be of 2,000 tons capacity, and designed to carry coal up the Thames to the new power station at Battersea.

The Norris Warming Co., of Manchester, have received a contract for the installation of heating plant at the Sheffield new Central Library and Art Gallery from the Sheffield Corporation.

Messrs. Beyer, Peacock and Co., Ltd., have received an order for a "Beyer-Garratt" locomotive, for operation on 1 in 18 gradients, and 90-ft. curves, from the Sneyd Collieries, Ltd., of Staffordshire. In addition, a repeat order has been received from the Peruvian Government for one "Beyer-Garratt" locomotive having a traction effort of 57,160 lb., and a weight of 178 tons.

Messrs. Ransome and Marles Bearing Co., Ltd., of Newark-on-Trent, have been awarded a contract for split roller bearings by the Egyptian State Railways Administration.

Messrs. G. D. Peters and Co., Ltd., Slough, have secured contracts for 50 sets of air-brake equipment for the Calcutta Tramways, and for various fittings required by Messrs. Ransomes, Sims and Jeffries, Ltd., of Ipswich, for omnibus bodies they are building to the order of the Egyptian Omnibus Co.

Messrs. Beyer, Peacock and Co., Ltd., have been awarded a contract for five three-cylinder compound express passenger locomotives for the Great Northern Railway Co. (Ireland).

The Metropolitan-Cammell, Carriage, Wagon, and Finance Co., Ltd., have received a contract for one hundred and twenty-eight 25-ton all-steel hopper ballast wagons.

The Consolidated Brake and Engineering Co., Ltd., Slough, have received an order for the supply of vacuum-brake equipment for 30 bogie wagons being built by the Metropolitan-Cammell Carriage, Wagon, and Finance Co., Ltd., for the Sierra Leone Development Co., Ltd.

Catalogues and Other Publications.

The extraordinary corrosion of metals by contaminated waters, especially close in shore, is the subject of a new booklet dealing with Sheathing Metals, recently published by I.C.I. Metals, Ltd. Although the booklet deals with an improved form of Muntz's Metal sheathing developed to cope with the sheathing corrosion troubles which have tended to increase in recent years for various reasons, there are certain localities in which water conditions are against even this improved Muntz's alloy. In fact, in such water brass cannot be expected to give anything but very short life, for which reason other alloys have been developed, the principal of which are Elio and Cupro-Nickel, the former being strongly recommended where water conditions are known to be abnormally severe, and the latter for use under all conditions. By reason of its greater strength and its apparent non-corrodability, Cupro-Nickel can be used in thinner gauges than others. This booklet will be of interest to marine engineers and builders of bridges, piers, docks and wharves in tropical and semi-tropical countries, and to architectural engineers. Copies may be obtained on request from Imperial Chemical House, Millbank, S.W. 1.

The Bureau of Information on Nickel of the Mond Nickel Co. has issued a booklet entitled "Nickel Alloy Steels." It deals with the effect of nickel, the effect of chromium with nickel, nickel-chromium-molybdenum steels, other alloys containing nickel, and typical properties and applications. As the publishers themselves observe, the number of these steels and the variety of their applications are now such that a publication of this size can only review them briefly. Nevertheless, this is a very useful publication. It contains a number of interesting illustrations.

We have received a very interesting brochure containing information and particulars of the Brackelsburg furnace. This furnace, which is fired with pulverised fuel, is designed for melting ferrous and non-ferrous metals and alloys. Modern demands for improved material and for improved melting methods necessitate furnaces which are free from metallurgical limitations, and yet are economical in use. Those who have in mind new melting furnace installations will find a perusal of this brochure informative, and a copy can be obtained on application to James Howden and Co., Ltd., Caxton House, Westminster, S.W. 1.

McKechnie Brothers, Ltd., have sent us a most informative brochure containing particulars of theri various products. This firm specialise in brass and bronze rods and sections, solid metal pressings, chilled cast bars, anti-friction metals, and non-ferrous metal alloys, which cover a very wide range of service. Possessing an excellent plant and efficient staff, this firm is able to supply the highest classes of material and information regarding non-ferrous metals and alloys, their manufacture and application, is always at the service of customers. A copy of this brochure is available on application to the firm at Rotton Park Street, Birmingham.

IRON AND STEEL REPORT.

FIRST and foremost among the factors that have influenced the iron and steel markets during the past month has been the vigorously conducted campaign to secure from the Government some measure of tariff protection against foreign products. At the moment of writing, the indications are that action will be postponed until early next year. There seems to be little room for doubt that the Government will eventually take steps to ease the situation of the British iron and steel industry, but there is little doubt also that the nature of those steps will only be decided upon after careful examination of the entire field, and a close analysis of the extent of the reaction upon the consuming industries. It is a situation that bristles with difficulties, and one which calls, perhaps, for keener discrimination than was the case with many of the other industries that have already been accorded tariff benefit.

Probably the weakest factor of the steel trade to-day, as it has been for some considerable time, is the poor demand from the shipyards for plates and other classes of shipbuilding materials. The position on the North-East Coast and on the Clyde has been improved to some extent recently by the placing of a number of orders for vessels of various kinds, but in the aggregate these have accounted for a relatively small tonnage of steel. It is this factor which is largely responsible for the formidable decline in output at British rolling mills. It may be recalled that since about 1927 rebates of a substantial character have been granted by steel rollers to shipbuilders who have confined their steel purchases to British works, and also that during the past few months steel manufacturers have agreed to a levy amounting to £100,000 altogether, to enable them to grant additional subsidies to British shipyards. It is understood, moreover, that North-East Coast and Clydeside rollers have expressed their readiness to enter into a permanent arrangement with the shipbuilders, under which the shipyards will not be penalised by any protection granted to the iron and steel trades.

Recent production statistics of the National Federation of Iron and Steel Manufacturers can hardly fail to convey the full measure of the decline in output in this country. Since the departure from the gold standard in late September, with its beneficial influence on certain industries, including certain users of iron and steel, the production of these materials has registered a marked increase, but even so the tonnage is well below the monthly average of last year. In the case of pig iron, for example, the October output amounted only to 284,200 tons, compared with a 1930 monthly average of 516,000 tons, and an average in 1913 of 855,000 tons. The decline is less pronounced in the case of steel ingots and castings, though it is serious enough. The production of these in October was 457,400 tons, against last year's average of 608,000 tons, and a pre-war average of 638,000 tons.

The price position almost throughout the range of iron and steel products during the past month has been steady, and very little actual change in values has occurred. Pig iron consumption at the moment shows definite indications of a seasonal tapering off, but otherwise the demand of late has been about maintained at the slightly improved level of the past two months or so. There is, however, extreme difficulty in effecting any further measure of improvement. In finished iron, there has been a moderate movement of marked bars, but the demand for common bars remains disappointing, and with many users of these becoming more closely wedded to steel, former outlets are gradually closing up. The steel position so far as the shipbuilding demand is concerned has already been discussed. The consumption of structural steels in most important centres is also very much below normal, and the same may be said in respect of locomotive boiler and frame plates. The demand from most other heavy branches of consumption also leaves much to be desired. Latterly, however, improvement has been reported for bright-drawing bars.

Notable Floating Dock for New Zealand.

The Methods Adopted to Prevent Corrosion.

Some time ago there was launched on the Tyne by Swan, Hunter and Wigham Richardson, Ltd., a very large floating dock built in three sections for the port of Wellington (New Zealand), and in the middle of July last this dock, in charge of powerful ocean-going tugs, started out on its long voyage from England to New Zealand, about 13,500 miles, which is apparently the longest tow ever attempted. Approximately seven months will be required for the operation, the dock being due in Wellington next January.

In view of all the attention now being given to the prevention of corrosion, causing a loss of many million tons of steel per annum, of which one of the latest examples, of course, is the "First Report on the Corrosion of Iron and Steel," it is interesting to note the new dock is painted with red lead paint. For more than a century past this has been recognised to possess valuable qualities for the protection of iron and steel against corrosion, especially under the severe conditions of sea air. If the painting is carried out on right lines, with adequate scraping and cleaning of the surface before the paint is applied—say, three coats, as well as an extra preliminary daub for the rivets—iron and steel are preserved in remarkable fashion. This is shown by the experience resulting from hundreds of lighthouse,, dock and harbour buildings, ships, floating docks, cranes, bridges, oil tanks, and gasholders that have been painted with red lead, as well as special structures such as the Blackpool Tower, 480 ft. high, which is in excellent condition to-day after forty years' exposure.

Important also is the fact that the modern use of special non-setting red lead, containing about 94% actual red lead (plumbic tetroxide), less than 6% lead monoxide, and 99½% total lead oxide, means that paint of this description can be supplied in bulk, as it will keep without setting in storage containers. Non-setting red lead is made by controlling the manufacture with great accuracy, the process consisting in oxidising molten lead with air in two stages, first at not over 650° F., to yellowish lead monoxide (litharge) known as "drossing," and then at a higher temperature, but below about 1,000° F., to read lead, an operation termed "colouring," because of the change from yellow to red. In ordinary red lead the presence of excess of lead monoxide causes the setting or semi-solidification of linseed oil used in paint manufacture, but, as stated, this difficulty has now been eliminated without sacrificing any of the valuable rust- and corrosion-resisting properties of the paint.

British Industries Fair.

The increased tendency of overseas countries to buy British goods is indicated by inquiries which are being received at the offices of the British Industries Fair in London and Birmingham.

The number of overseas trade buyers who have informed the Department of Overseas Trade of their intention of visiting the Fair is much greater than at the same time last year, and it is stated that the majority of them were newcomers. Many have instructed their United Kingdom agents to represent them at the Fair. A remarkable number of inquiries have been received with reference to a wide range of manufactures and products, with inquiries for textiles predominating.

The inquiries received at Birmingham so far are for aeroplane tools, building material, car factory equipment, cycle parts, electrical gear, foundry equipment, gas boilers, gearing, grinding machines, hollowware, motor-cycles, oil, oil engines, oilcloth, paints and brushes, packing-case machinery, petrol locomotives, red lead, sanitary fittings, shot guns, spraying lacquer, stainless steel, textile machinery, transformers, tinplates, tubes, tools, and wire netting. The biggest of all is an inquiry for a complete gas works for a town of 300,000 inhabitants in Greece.

Holland, as usual, heads the list of prospective buyers at the Fair, with France, Canada, Denmark, Spain, Germany, and Switzerland following on. There are also numerous replies from Poland, Italy, and the Irish Free State, and a few from countries as far away as China, Japan, Dutch East Indies, Portuguese East Africa, Siam, Australia, and New Zealand.

The space available at Olympia, Birmingham, at the White City at which various sections of the Fair will be held, are now almost wholly taken up, and the prospects of a successful Exhibition are very bright.

MARKET PRICES

ALUMINIUM.

99% Purity	£85	0	0

ANTIMONY.

English	£40	0	0
Chinese	29	0	0
Crude	20	0	0

BRASS.

Solid Drawn Tubes	lb.	10d.
Brazed Tubes	lb.	12d.
Rods Drawn	,,	8¾d.
Wire	,,	8¾d.
*Extruded Brass Bars	,,	4¾d.

COPPER.

Standard Cash	£37	12	6
Electrolytic	45	0	0
Best Selected	39	5	0
Tough	39	0	0
Sheets	75	0	0
Wire Bars	47	15	0
Ingot Bars	47	15	0
Solid Drawn Tubes	lb.		11d.
Brazed Tubes	,,		11d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	11½
		Plus 20%		
‡Ferro Tungsten	,,	0	1	8½
		Plus 20%		
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	33	2	6
NOMINAL 4-6% Carbon, scale 8/- per unit	,,	24	0	0
NOMINAL 6-8% Carbon, scale 8/- per unit	,,	23	0	0
NOMINAL 8-10% Carbon, scale 8/- per unit	,,	22	10	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	36	0	0
Guar. max. 1% Carbon, scale 15/- per unit	,,	39	17	6
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	40	10	0
‡Manganese Metal 96-98% Mn.	lb.	0	1	6
‡Metallic Chromium	,,	0	3	0
§Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/6 per unit	,,	7	12	6
45/50% basis 45%, scale 5/- per unit	,,	10	17	6
70/80% basis 75%, scale 7/- per unit	,,	16	8	6
90/95% basis 90%, scale 10/- per unit	,,	23	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12	7	6
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	17	10	0

FUELS.

Foundry Coke—						
S. Wales	£1	2	6			
Sheffield Export	0	14	0	to	0	15	0
Durham					15	0
Furnace Coke—						
Sheffield	0	14	0	to	0	15	0
S. Wales	0	16	6	to	0	17	6
Durham	0	15	0			

GUN METAL.

*Admiralty Gunmetal Ingots (88:10:2)	£52	0	0
*Commercial Ingots	44	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9½
*Cored Bars	,,	0	0 11½

LEAD.

Soft Foreign	£15	0	0
English	16	10	0

MANUFACTURED IRON.

Scotland—						
Crown Bars	£10	5	0			
N.E. Coast—						
Rivets	11	0	0			
Best Bars	10	10	0			
Common Bars	10	0	0			
Lancashire—						
Crown Bars	9	15	0			
Hoops	12	0	0			
Midlands—						
Crown Bars	£9	15	0	to	10	0	0
Marked Bars	12	0	0			
Unmarked Bars			—			
Nut and Bolt Bars	£8	7	6	to	8	12	6
Gas Strip	10	12	6			
S. Yorks.—						
Best Bars	10	15	0			
Hoops	£10	10	0	to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	11d.
†Sheet to 10 W.G.	,,	11½d.
†Wire	,,	12⅞d.
†Rods	,,	11½d.
†Tubes	,,	1/5
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	8	6
Foundry No. 1	3	12	0
,, No. 3	3	9	6
N.E. Coast—			
Hematite No. 1	3	5	6
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	3	14	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
,, Foundry No. 3	3	6	0
Northants—			
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
,, Foundry No. 3	3	6	0
West Coast Hematite	4	3	6
East ,, ,,	3	5	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6	0	0	to	£7	0	0
Bars, hammered, basis	£16	10	0	,,	£17	10	0
Blooms	£10	0	0	,,	£12	0	0
Keg steel	£32	0	0	,,	£33	0	0
Faggot steel	£18	0	0	,,	£24	0	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£32	0	0			
,, Braziery	30	0	0			
,, Wire			—			
Brass	24	0	0			
Gun Metal	28	0	0			
Zinc	7	15	0			
Aluminium Cuttings	62	0	0			
Lead	13	0	0			
Heavy Steel—						
S. Wales	2	7	6			
Scotland	2	2	6			
Cleveland	2	2	6			
Cast Iron—						
Lancashire	2	8	0			
S. Wales	£2	7	6	to	2	8	6
Cleveland	£2	5	6	to	2	7	6
Steel Turnings—						
Cleveland	1	12	6			
Lancashire	1	2	6			
Cast Iron Borings—						
Cleveland	1	6	0			
Scotland	1	12	0			

SPELTER.

G.O.B. Official			—
Hard	£11	5	0
English	15	0	0
India	13	5	0
Re-melted	13	0	0

STEEL.

Ship, Bridge, and Tank Plates—						
Scotland	£8	15	0			
North-East Coast	8	15	0			
Midlands	8	17	6			
Boiler Plates (Land), Scotland	10	10	0			
,, ,, (Marine) ,,	10	10	0			
,, ,, (Land), N.E. Coast	10	0	0			
,, ,, (Marine) ,,	10	10	0			
Angles, Scotland	8	7	6			
,, North-East Coast	8	7	6			
,, Midlands	8	7	6			
Joists	8	15	0			
Heavy Rails	8	10	0			
Fishplates	12	0	0			
Light Rails	£8	10	0	to	8	15	0
Sheffield—						
Siemens Acid Billets	9	2	6			
Hard Basic	£8	2	6	and	8	12	6
Medium Basic	£6	12	6	and	7	2	6
Soft Basic	6	0	0			
Hoops	£9	10	0	to	9	15	0
Manchester—						
Hoops	£9	0	0	to	10	0	0
Scotland, Sheets 20 W.G.	9	10	0			

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten	lb.	2/9
Extras		
Round and Squares, ⅛ in. to ½ in.	,,	3d.
Under ¼ in. to ⅛ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅛ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£136	15	0
English	138	5	0
Australian	138	0	0
Eastern	143	0	0
Tin Plates I.C. 20 × 14 box	13/6 to 13/9		
Block Tin Cash	£138	7	6

ZINC.

English Sheets	£24	10	0
Rods	32	0	0
Battery Plates	20	5	0

* McKechnie Brothers, Ltd., quoted Dec. 9. † C. Clifford & Son, Ltd., quoted Dec 9. ‡ Murex Limited, quoted Dec. 9.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Prices quoted Dec. 9, ex warehouse.